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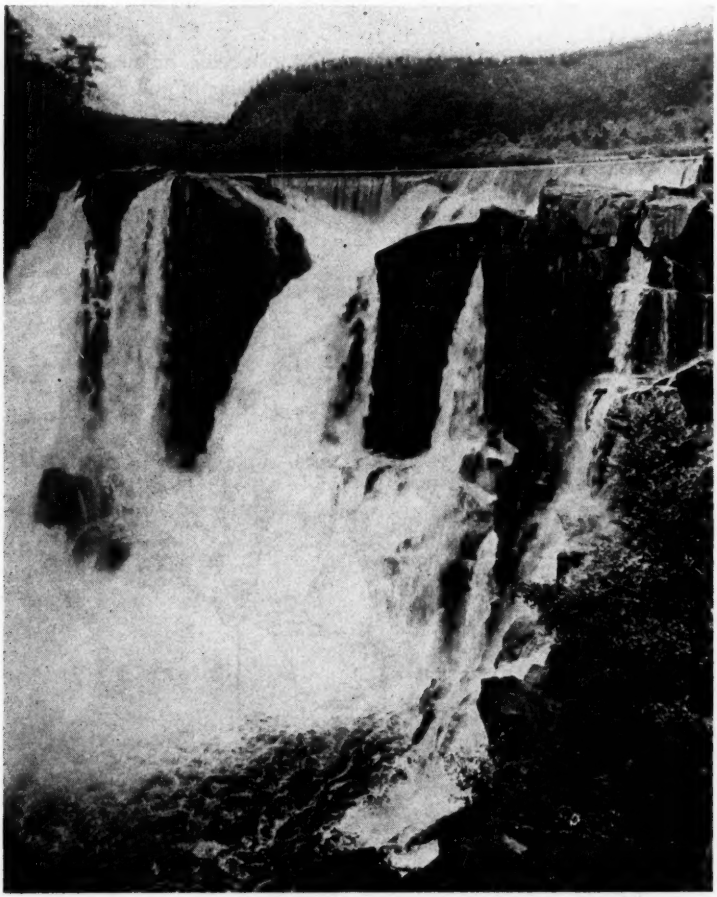
Want to take a dip in any one of Minnesota's 11,324 sparkling lakes; or drive leisurely over more than 11,000 miles of scenic highways, or enjoy a friendly game of golf on any one of the state's 250 resort courses? Or how about a hiking trip through a cool, pine-scented Northern forest or a canoe trip into the primeval wilderness of Minnesota's north country? Vacation by

PRINCIPAL HIGHWAYS AND RESORT CENTERS—are located on this map of Minnesota, vacation wonderland of the north country.

plane, train or motor for happy, contented hours in this Northern wonderland, for living is good in Minnesota.

members of the American Society for Engineering Education who will attend the annual meeting June 18–21, at the



THE GRANDEUR OF THE HIGH FALLS—on Pigeon River on the Canadian border can be seen during your vacation in the Minnesota northern wonderland of cathedral-like forests, sparkling lakes and rippling rivers.

Come a week or two early, if you can, to Minnesota, "Land of the Sky-Tinted Waters" with its friendly, hospitable people who are waiting to welcome

University of Minnesota in Minneapolis. If time permits, linger awhile after the convention and enjoy yourself in this summer wonderland.

The summer days are long in Minnesota, long enough to enjoy even a short vacation among the state's ten thousand lakes full of muskies, pike, trout, and pan fish; boundless game-filled forests, thrilling scenic highways, and canoe trails of the pioneers.

See the grandeur of Lake Superior's North Shore, and enjoy the clear, temperate, invigorating summer air. You get the most out of a vacation in Minnesota, for the state has everything.

Children will revel in the wide, sandy beaches of Minnesota lakes. Sand castles can be built as fanciful as those of Oz, or the small ones can splash in the sun-warmed waters while the soft rays of the Northern sun turn them into golden brown Indians.

For those who hike and ride for their principal entertainment, there are miles of leafy, sun-speckled trails where time is unimportant and space is limitless. Sailing in Minnesota, for those who care for the heightened exhilaration of the race, will offer enthusiasts new thrills. On the skimming dish type of double center-board boats of the famous E and C classes, the crews sometimes balance on the hull and often on the center board itself in the heat of the race. Every minute is packed with adventure and when the sail is furled, even the beginner is a fresh-water salt.

And one of the most convenient things about vacationing in Minnesota is the fact that vacation costs always have been and today remain reasonable

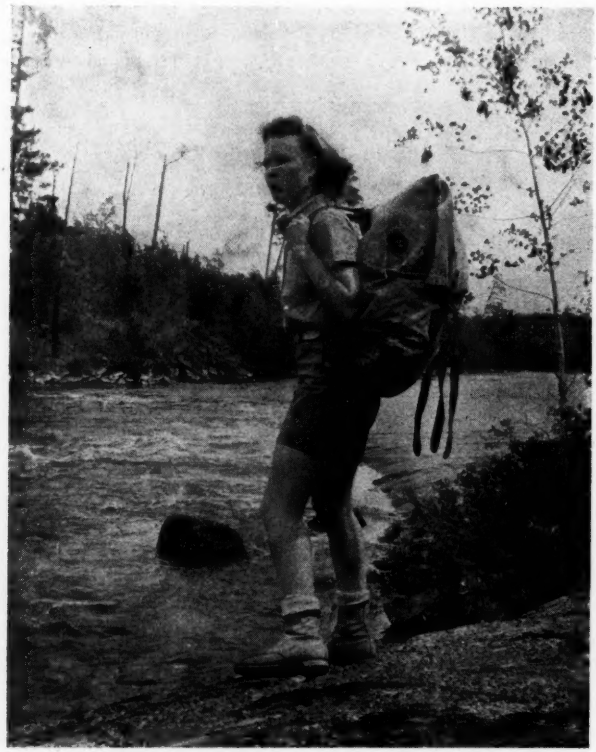
A CANOE TRIP—to the painted rocks on Lac LaCroix can be an adventure highlight during a memorable vacation in Minnesota, land of Paul Bunyan and his great blue ox.

in the state. Regardless of your budget, there is an outing to fit it.

Most resorts are located on lovely lake shores where you can make the most of the restful surroundings, magnificent scenery and a fine summer climate, of an average 68.3 degrees.

Resort accommodations depend upon your demands. They run from $4 a day and up on the American plan. Supervised recreation, riding stables, tennis courts and other outdoor sports are available at many resorts, and golf courses are usually accessible even in the remote counties.

Housekeeping cabins are available at many resorts, and the costs depend upon the size and luxuriousness you require, but they run as low as $21 per week. Usually completely furnished, including cooking utensils, china and silverware, the cabins are, for the most



ALL YOU NEED—for a wonderful walking trip along any one of many magnificent Minnesota trails can be packed in a single rucksack. Minnesota forests, lakes and rivers erase the cares of the city and allow the vacationist to return to his tasks refreshed and exhilarated.

part, conveniently located for obtaining ice, milk and groceries.

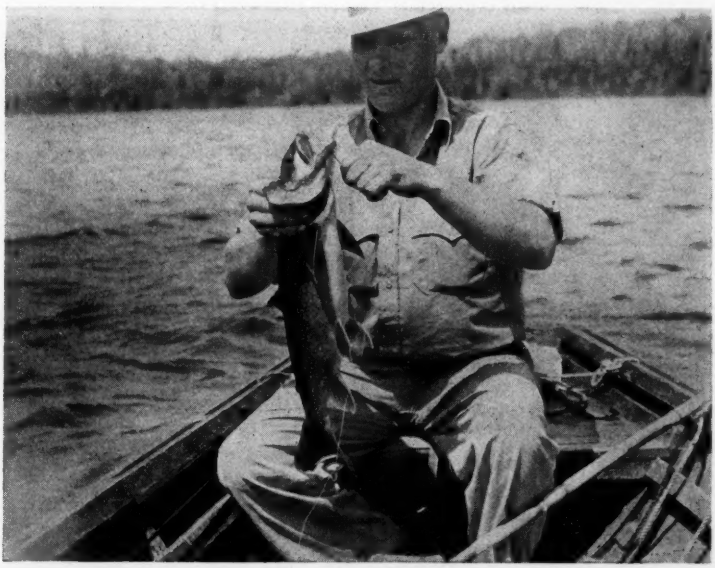
Cabin camps, auto courts and trailer parks are also located throughout the lake country, with prices ranging upwards from less than $1 a day.

If you a plan a sightseeing trip through the state, you can still find Indians living in Minnesota; and the signs of their earlier glory are to be found scattered across the land. In the southwest, near Pipestone, are the quarries where the red stone of peace pipes was cut and shaped, and everywhere within the state the fish leap in the glittering lakes.

You'll know you've been in a battle when you finally step ashore with a giant great northern pike or muskellunge draped on your back. They are plentiful in many Minnesota lakes, and run into tens of pounds. Not quite so ferocious but still bundles of explosive energy are the bass, the wall-eyed pike and other fish of the northern waters.

The whitefish and lake trout of Lake Superior are other favorites of the anglers, and there is nothing tastier than one of these delicately flavored fish baked with a few strips of bacon and served piping hot.

If you are a member of the fly-rod fraternity, there are streams where you can match your skill against the caprice and elusiveness of the brook trout. And lake trout can be hooked in any number of northern lakes including Superior and Trout Lake, a little south of famous



How Would You Like—to hook one of these explosive packages of fins and gills up at Brule Lake, Minnesota. This lucky angler is removing the hook from only an average sized lake trout to be had in Minnesota's northern waters.

Rainy Lake on the Canadian border.

Among the northern trout streams offering the wily gamesters are the St. Croix River, streams along the North Shore and the Pine County streams. In the south the White Water and Root rivers can be counted on for long hours of excellent fishing.

For lake fish, you can hook pan fish in any of Minnesota's lakes; pike at Mille Lacs, Long Lake, Crooked Lake and many of the northern lakes in the state; and the battling muskies in Cass Lake, Leach Lake, Rainy Lake and Lake of the Woods.

Visitors from other states may obtain a family bargain license at $4.50 which permits man, wife and accompanying children under 16 years to fish. The individual visitor or non-resident license is $3. Licenses may be obtained from county auditors, hardware, sporting goods stores and at resorts.

And when you are tired of fishing, try any one of the 250 golf courses located throughout the state. Minneapolis alone has a dozen or more within and just outside the city limits. Many resorts in the state have world-famous courses on their own grounds. Anyone attending the convention who desires to play golf will find the convention golf committee all set to make the necessary arrangements.

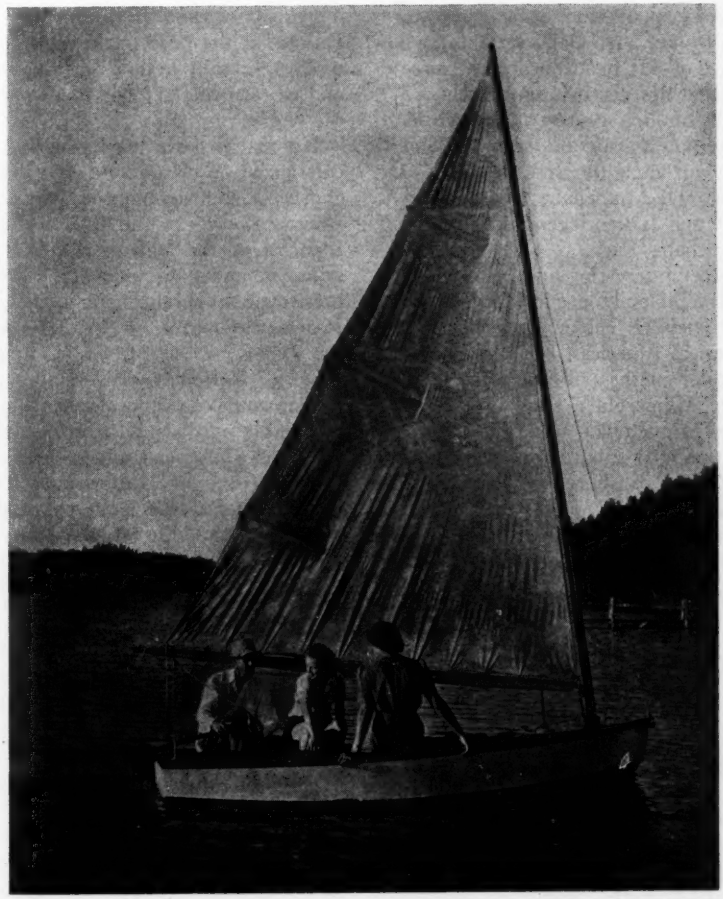
TUCKED AWAY—on the shores of one of Minnesota's 11,324 crystal-clear lakes is a comfortable log cabin just waiting for a group of vacationers to make use of it.

One important precaution to take when planning a Minnesota vacation is to write in advance for reservations at the resort of your choice. Information concerning resorts and recreation they offer may be obtained by writing

to the Minneapolis Chamber of Commerce, or the Gateway Tourist's Bureau in Minneapolis, or the Minnesota State Tourist Bureau, State Capitol, St. Paul 1, Minnesota.

Even if you must confine your recreational activities to the immediate convention area, you will find Minneapolis a summer sports playground and cultural center. The city's eleven lakes and 141 parks make up a 60 million dollar park system unequalled anywhere in the United States.

All the outdoor summer sports,



SAILING IS A MUST—in Minnesota, whether you prefer the small catboat, the racy C and E class boats, or whether you're a motor man. During the annual Minneapolis Aquatennial, sea-sled motorboat races are held on beautiful Lake Calhoun within the lovely residential district of Minneapolis.

swimming, boating, picnicking, golf, riding, and even fishing can be enjoyed within the city limits. Or visits to the University of Minnesota's art galleries, its museum of natural history, the Walker Art Gallery, and the Institute of Art in Minneapolis, can supplement the visitor's enjoyment.

The milling center of the world in Minneapolis can be seen in stately grandeur along the banks of the Mississippi; and Minnehaha Falls, famed in story and Indian legend, are located in Minnehaha Park.

Other interesting and historical sites are the Sibley House in Mendota, home of Henry H. Sibley, governor of the historical American Fur Company and a leader in the political activities that made Minnesota a state in 1858, and Lake Minnetonka, one of Minnesota's most popular suburban resorts, with its 110 miles of shoreline, just 12 miles west of the city.

St. Paul is the Capitol City and a great transportation center. Visitors can spend many hours of pleasant investigation in the Minnesota state capitol and the Minnesota Historical Society's museum.

For those who have time to visit Duluth, at the head of the Lakes, they will see literally millions of tons of ore and wheat being shipped to all parts of the world.

No matter how long you find you can spend in Minnesota you have a choice of metropolitan entertainment, summer sports, or the quiet scenic enjoyment of the state parks and both national and state forests. Among these famous beauty spots are Lake Itasca, the source of the Mississippi, the Dalles of the St. Croix, and the Superior National Forest, embracing a million acres of primeval lakes and forests in the northern part of the state.

Those who spend any part of their vacation time in Minnesota will find the state speaks the language of youth which says that life is good today and will be better tomorrow.

The Philosophy of Humanistic-Social Studies in Engineering Education*

By EDWIN S. BURDELL

Director of The Cooper Union

I

Introduction

When General Eisenhower was given the honorary degree of Doctor of Laws at the University of Richmond last March, he said after the award:

"I am sure I speak for the 3,000,000 Americans who fought in Europe when I say that their deepest hope for the future is that their sons will not have to undergo similar experiences.

"Veterans of this war are demanding the highest type of leadership to prevent this. They are looking to educational institutions to provide that leadership, but colleges and universities—our whole educational system—must go beyond producing the best doctors, or lawyers or engineers. Peoples must learn to live in peace with other peoples whose basic philosophy of life is different from their own."

Here is a challenge which no teacher in this room can ignore and, therefore, it is my purpose to discuss with you how and why humanistic-social studies can contribute that "plus" factor in engineering education which the enlightened citizens of our country are demanding. The humanistic-social stem of engineering education may be offered primarily in the form of facts and figures, drills, discussions, and exercises. But unless the basic philosophy behind the program is well thought out and thoroughly understood by administrator, teacher, and student, the subject matter in and of itself will not work the miracle that needs to be worked to produce engineering graduates in the future who will have that breadth and depth of vision and that tolerance to which General Eisenhower refers. The problem of reconversion in industry is something more than one of re-tooling; reconversion in engineering education is considerably more than the addition or subtraction of courses.

II

The Driving Force—Scientific Humanism

It is my obligation, therefore, to define as briefly and as clearly as possible what the driving force of the educational program of the engineering schools of the future is likely to be, namely Scientific Humanism.

I say Scientific Humanism advisedly, for the humanism of the past was too often identified with a pedantry more concerned with dead letters than with the exploration of nature and human nature. Indeed "humanism" has sometimes been so concerned with the "humanities" that it has actually been antagonistic to as well as ignorant of science. But today no department of human thought—from the fine arts to the social sciences—can flourish without

* Presented at the 54th annual meeting, S.P.E.E., St. Louis, June 20–23, 1946.

association with the exact sciences. A significant word or phrase does not come into use by accident but emerges out of a cultural situation. It is certainly more than a coincidence that George Sarton, the great historian of science to whom I am especially obligated, has used the phrase scientific humanism for many years. The late Professor Barry closed his stimulating book "The Scientific Habit of Thought" with a chapter on scientific humanism and Lancelot Hogben, the English biologist immersed in mathematics on the one hand and philosophy on the other, began his monumental synthesis "Science for the Citizen" with a preface on the meaning of scientific humanism. It is no coincidence that Whitehead who began as a mathematician and philosopher of the physical sciences grew into the great humanist of "Aims of Education," "Science and the Modern World," and "Adventures of Ideas."

When one listens to these learned men, it becomes obvious that one cannot be a good citizen or even a good scientist not to mention a good engineer without understanding that the scientific must be humane, and the humane scientific.

Scientific Humanism means a marriage of science and the accumulated culture of the past; it cannot tolerate separate disciplines moving along parallel lines in accepted grooves of departmentalization. Scientific Humanism is a fusion, a synthesis of science, art, and philosophy, a union out of which is born the intellectual life of the future.

The product of this educational philosophy will be not merely an engineer but a well-rounded man who has intellectual associations with fields other than his own.

He will be liberal, feared both by the reactionary and the radical, because he will believe in and protect the essential dignity of the individual. He will observe those three values which are basic to science as well as to democracy; freedom of speech, freedom of action, freedom for experimentation. He will have faith in the ability of people to work out their own solutions to problems. He will aim to preserve our democratic society because his education has made him both a citizen and a scientist.

The scientific humanist as a citizen and as a member of a profession will put into practice the "Canons of Ethics For Engineers" so ably phrased by our distinguished colleague, Dugald C. Jackson, and he will observe especially the following canon: "The engineer will interest himself in the public welfare and be ready to apply his special knowledge, skill, and training for the benefit of mankind."

Scientists and engineers now have the terrifying responsibility of controlling atomic energy. Whether commercial applications come in the next year or in the next generation, the fabrication and detonation of the atom bomb last summer put the world into a short-sheeted bed. Never again can we pull the covers up over our heads. We are faced with the stark alternative of one world or no world. Unless the art of human relationships is perfected very quickly, we shall find it difficult to live on the same planet with the terrible products of scientific research and engineering development stimulated by the exigencies of war. Bacterial warfare, jet-propelled planes, and guided missiles are but a few of the weapons with which we must learn to cope, and we must learn fast!

Along with our technical skill we

must have wisdom, but wisdom, ultimately the product of experience, can be possessed only by men and women who have been educated as well as trained. To be wise is to know how to be tolerant, magnanimous, and sympathetic with peoples and cultures other than our own. We can achieve these qualities in part by showing students how to withhold criticism until essential facts are known; how to withhold action until consequences are studied; how to withhold judgment until all values, human as well as material, are assessed. No doubt the way for these humanistic qualities is prepared by that scientific suspension of judgment which is the foe of dogmatism and bigotry. But mere suspension of judgment about another person or about a people is not in itself sympathy or understanding. There is needed further positive scientific inquiry but it must be enriched by contact with the humane arts and by association with teachers who in this sense are artists.

The student educated in a liberal as well as a scientific atmosphere will act as a brake if not a preventive to pressure groups having their ruthless way. He will be neither pro-labor nor anti-labor. His role in society will be constantly changing; as the possessor of the know-how of our industrial machine, he will be the servant of none and the champion of all.

We hope that the engineering students of the future will carry over the methods of science that they have learned in classroom and laboratory into the problems of social relations, always allowing, of course, for the fact that society is neither a classroom nor a laboratory. We expect that an integration of the sciences and the humanities will make our students less susceptible to the prevailing shibboleths, clichés, and slogans regarding races, creeds, and political programs. Granted that stereotyped reactions are easier and apparently swifter than the scientific habit of thought, they are infinitely more dangerous than ever before.

III

Levels of Discourse

We all recognize that one of the great stumbling blocks to achieving a unity in our educational program is the fragmentation and departmentalization of learning. This seems to be an unavoidable consequence of the pursuit of knowledge. Our college staffs are composed of specialists, some of whom have achieved fame by research into a minute aspect of a whole field. Is it not absurd then to expect an undergraduate to see the whole in terms of its parts when he is exposed in most classes to those minds who are concerned with the minutiae of a subject? What is needed are teachers who are not only masters of their subject and lucid expositors but in addition are quick to see the inter-relationships between fields of learning as well as able to excite the student's interest in any one of them. This is not to say that I believe that physics teachers should teach English or that deans of engineering should teach philosophy any more than that English teachers or philosophers should be expected to teach physics or run the college of engineering.

When a solution to an engineering problem is being sought, the engineer uses the scientific level of discourse appropriate to his problem; he uses scientific instruments made for the express purpose of measuring and testing the materials with which he works. If the civil engineer is faced with a

problem in hydraulics, he does not look for his answer in poetry or in art; he turns to the investigations of other scientists, to the instruments of his laboratory, etc. But similarly, if the engineer, as a member of a social community, is faced with a problem in social dynamics, he does not turn to the findings of his laboratory, but rather to the methods and content of the social sciences. Each problem draws its knowledge from many levels, each integrated with the other, but neither problem may be solved solely at a level of discourse inappropriate to it. This may seem like the most common common sense. But observe how often not only the engineer but the non-professional layman will attempt to build his entire philosophy on a single set of principles drawn from a single level of organization. All levels are used on occasions, but they must not be confused, nor one substituted for another.

Man, and especially man in society, cannot be talked about solely in terms of his chemical composition, any more than he can be talked about or known as a complete organization solely at the level of the biological sciences. Moreover, as Arthur Koestler says * in "The Yogi and the Commissar":

> "The 'reduction' of social values like courage and self-sacrifice to the psychological level of masochism, the death instinct, etc., is a process analogous to the reduction of live organisms to their chemical components. For on the sociological level the individual emerges as part of a new whole, and the integrative relations on this level are once more specific and irreducible."

Man in society is so extremely complex an organization, different as a whole from any part or from the mere sum of the parts, that no one method of investigation, no one frame of reference, whether it be chemical, biological, or psychological, can know all or describe all.

Humanistic studies make available a level of discourse appropriate to personal and social problems which cannot be solved at any other level, even though they may be related to all other levels, and even though all the levels may be drawn into relationship by the problem.

IV

Liberal Studies should not be "Slanted"

It is a mistake to assume that all problems can be solved at a single level of discourse; it is also a mistake to assume that the humanities can be approached only through the history of science and engineering or taught only through especially prepared texts such as "English for Engineers," "Economics for Engineers," etc. In the first place, it is misleading to the student and promotes rather than minimizes the unfortunate notion of fragmentation of learning. If we wish the engineering student to participate in the whole fabric of our culture, then divisive terms as well as segregated subject matter must be avoided. There is a grave danger involved in presenting the student with but a single point of view, a single method of critical analysis, a single level of discourse. If the student is trained to see his whole world, every department of his and others' behavior, all problems—personal, social, and technological alike—solely from the technological point of view, his analyses will be warped and prejudiced.

In the second place, it is a mistake to assume that the engineering student has an interest in and aptitude for

* Macmillan, 1945, p. 241.

liberal studies only when they are presented technologically. His antagonism, if any, to English, foreign languages, and social studies is likely to be a carry-over from the indifferent teaching of these subjects in high school. Also there is a mistaken notion —all too prevalent—that if a boy is good in and likes mathematics or physics, he must necessarily be poor in and not like English or history. Actually, neither statistics nor observations support this negative correlation.

V

Objectives, Subject Matter, and Sequence

In addition to discussing the philosophy of the humanistic-social stem, it seems to me that I should give you some idea of what I have in mind as to objectives and content.

Humanistic studies, if they are to make their maximum contribution to engineering education, must be considered in relation to the sum total of engineering education. During the past few years, faculties of many engineering schools have had to face many different types of curricular and methodological problems. How much and what kind of courses and subject matter should go into the humanistic-social stem? What is the purpose of this stem? Is there too much engineering specialization at the expense of basic scientific principles? How much and what kind of integration should occur in the curriculum?

Answers to these questions, if answers are possible at all, can be obtained only after the formulation of a common goal for engineering education. An explicit statement of what the sum total of engineering education should be would serve as a frame of reference within which is sought solutions to instructional problems.

The goal of engineering education can be stated in terms of its graduate. The engineer, as a member of a democratic society, is a valid point of departure in formulating a definition of the desirable graduate. Stated more specifically, this means that the engineer should participate effectively in a rational and democratic solution of technical, personal, and social problems. This basic postulate reveals that the scientific and humanistic aspects of engineering education are really one. It is the basis for the solution of the whole problem of engineering education.

This point of departure leads to two inescapable conclusions: first, that the single over-all goal of engineering education is the development of a problem-solving ability: I don't mean by problems the exercises which are found at the end of the chapter or end of the text, but the broader knotty hurdles which each new day brings and which are to be overcome before the day ends. Secondly, the subject matter to be dealt with in the curriculum as a whole should be determined directly by the nature of the problems which confront the prospective engineer.

Problem solving, as an over-all ability to be developed, may be translated into personal characteristics to be attained by the desirable graduate. These characteristics involve:

A Spirit of Inquiry,
Knowledge of Sources of Information,
Knowledge of Concepts and Principles,
Knowledge of Methods of Problem Solution,
Skill in Manipulation of Engineering Devices and Materials,
Skill in Verbal and Graphical Representation and Communication,

Possession of Personal Standards of Accomplishment,

Possession of a Desirable Personal Philosophy.

The conclusion that the development of these characteristics should represent the sum total of engineering education is significant because it explicitly states the educational contribution in terms of the student rather than in terms of a series of courses. This point is emphasized by the fact that the development of those desirable traits or characteristics is much more a function of the instructional methods employed than of the subject matter of the curriculum.

Valid engineering education will, therefore, develop and advance problem-solving characteristics of the student. Subjects have a legitimate place in the curriculum only when through their teaching they contribute significantly to such characteristics. For example, the presence of any subject in the curriculum should be questioned if it does not contribute to the student's spirit of inquiry. The goal of problem-solving can be achieved only by a united effort on the part of the entire teaching staff.

Reformulating the aims of engineering education in terms of problem-solving provides a key position for the humanistic-social stem in that it offers at another level of discourse an equivalent opportunity for problem-solving in the realm of those values which are social and personal. At the same time, the problem-solving approach encourages the student to an increased awareness of the inter-relationships of the various disciplines.

Actually humanities courses can be selected and arranged to complement the scientific courses in method and approach so that the student's passage from the broad and general to the narrow and specific in his scientific courses is balanced by transition from the concrete to the abstract in his liberal courses.

In designing the curriculum, three subjects should be fixed and immutable: English Composition, Public Speaking, and Economics. Any program of college studies quite obviously needs to provide for training in the use of English, for the development of acceptable speech habits, and for some attempt to offset the economic illiteracy prevalent in America. But a curriculum must be broad enough to provide for more than fundamental skill courses.

An introduction to the historical evolution of social institutions must form the basis of the Humanities program. It is not difficult to convince the student that historical and social data develop that mature attitude which only a knowledge of the past can give to the present. Moreover, it is out of this background of closely related subject matter that materials needed in other Humanities courses in the curriculum will emerge. Even the skill subjects like English Composition may draw for their theme work and readings from literature that is related to the study of history.

It is, for instance, this emphasis on the historical background that encourages cooperation with local museums where displays of rich artistic materials give a three-dimensional stimulation to the student's interest and imagination and demonstrate at the same time the interweaving of cultural ideas. For example, while as history students young engineers may be studying the eighteenth century, in their English classes they may be reading an eighteenth-century novel and supplementing both by attendance at an exhibition

which can be mutually arranged by the school and the museum to demonstrate the impact of the development of fast sailing vessels and later of steam on the opening of the Far East and its commercial and political consequences. For instance, such an exhibition arranged for at The Cooper Union on "The China Trade and its Influence on the Western Arts from 1700 to the Opening of the Suez Canal in 1869," attracted very favorable comment not only in educational but in art and commercial circles in New York City.

After the student has received instruction in the skills applicable to written and spoken English, and after he has surveyed the history of his cultural heritage, he is prepared, in the upperclass years, to undertake more advanced examination of some of the major ideas which have served as the motivating concepts of western civilization. It is desirable that he should be acquainted with the great literature of the past, that as an educated man he should have learned something of the major cultural concepts of the last four centuries—esthetic, literary, religious, social, scientific, and political ideals that have preceded and in part formed twentieth-century thought. I wonder how many engineering teachers have taken the trouble to investigate the texts used by their Humanities Department, to read them and obtain the same bird's eye picture which is provided for their students.

Social studies such as Economics should not be offered until the student has amassed sufficient information on our social history and our institutions to have some sense of their complexities; he should be mature enough so that, properly guided, he will not be prey either to superficial shibboleth or to conditioned stereotype. The current tendency to examine trends without first looking at the facts involved in the formulation of those trends is ridiculous. It is for this reason, therefore, that Economics should be placed late in the curriculum. Economic institutions are best considered in relation to other social institutions; hence Economics is to be considered not only as an academic collection of laws and principles but also as an integral part of an introduction to the social sciences.

A sound personal philosophy should be the capstone of the structure of the humanistic-social studies. If the young engineer is to profit from the variety of studies which has just been described and if his point of view is to be shaped by them, then a successful effort must be made in his final year in college to unify and integrate his information. This can best be done by an exploration of the points of view and philosophies of the great minds of the contemporary world, of thinkers who have influenced the course of contemporary thought. I have in mind such men as Alfred North Whitehead, A. S. Eddington, and John Dewey. Their theses must be made available without imposing excessive reading assignments. This can be done by judicious selections elaborated by a stimulating and well-informed teacher in informal seminars where active discussion and argument provide the adhesive which makes the subject matter stick to the student's memory.

VI

Implementation—Academic Strategy

Having pointed out what I believe are the basic philosophy and the objective of the humanistic-social stem, and what it consists of in terms of objectives, subject matter, and sequences,

I want to conclude with a word about its implementations in the engineering college curricula. No amount of "pressure" from deans, presidents, or alumni can bring a faculty around to wholehearted support of the humanistic-social studies.

To be sure the administrative officers must be alert to lend a hand here and there when an important committee proposal extending the time and scope of the humanities is up for adoption, when English and the social studies are competing with mathematics and soil mechanics for appropriations, or when overloaded schedules tend to push the "less important" humanistic studies into such odd class hours as "eight o'clocks," noon hours or Saturdays.

But as I said before, salvation must come from within. Reconversion of the educational curricula must be a matter of the spirit as well as of the catalog. Students and faculty and administration must see for themselves that a humane education is necessary to the future of our civilization. They must be prepared to sacrifice nineteenth-century ideals of purely technical training to the demands of the modern world. Certainly, no one can fail to see the need in our society for leaders who are broad, liberal, and humane, as well as efficient. The first step toward this goal is a professional education such as I have described.

I can think of no better way to bring to a close what I have said than to quote that magnificent passage from John Henry Newman's essay on "The Aim of a University Education":

"If then a practical end must be assigned to a University course, I say it is that of training good members of society. Its art is the art of social life, and its end is fitness for the world. It neither confines its views to particular professions on the one hand, nor creates heroes or inspires genius on the other. Works indeed of genius fall under no art; heroic minds come under no rule; a University is not a birthplace of poets or of immortal authors, of founders of schools, leaders of colonies, or conquerors of nations. It does not promise a generation of Aristotles or Newtons, of Napoleons or Washingtons, of Raphaels or Shakespeares, though such miracles of nature it has before now contained within its precincts. Nor is it content on the other hand with forming the critic or the experimentalist, the economist or the engineer, although such too it includes within its scope But a university training is the great ordinary means to a great but ordinary end; it aims at raising the intellectual tone of society, at cultivating the public mind, at purifying the national taste, at supplying true principles to popular enthusiasm and fixed aims to popular aspiration, at giving enlargement and sobriety to the ideas of the age, at facilitating the exercise of political power, and refining the intercourse of private life.

The Engineering Colleges and the U. S. Office of Education *

By HENRY H. ARMSBY

Specialist in Engineering Education, U. S. Office of Education

It is my purpose in this paper to discuss briefly some of the problems facing the engineering colleges and the types of aid which the Office of Education, particularly the Specialist in Engineering Education, may be in a position to render the colleges in their solution. In the battle to "win the peace" in which our country is engaged, education is the most powerful branch of our fighting forces, with technical and scientific education in the position of the shock troops—the first to strike the enemy—the "C.B.'s" of our task force. Upon the engineering colleges is laid the task of preparing young men and women to understand and to aid in the technical and scientific advances which are developing with such speed and complexity as to constitute a scientific and ideological revolution.

This is a huge task and a grave responsibility, but it is only a part of the burden now resting on the engineering colleges. It will not be sufficient to produce mere technical and scientific competence. In fact many believe it may be positively harmful to society to do so, unless those who have the competence have also a vital awareness of the social, political, and economic implications of scientific and technical developments, and the ability to do something about them.

The development of these attitudes and skills cannot be separated from the development of technical and scientific attitudes and skills. Each must be an integral part of a unified program designed to produce men and women who can intelligently use the scientific method in attacking social and political problems, and can appreciate and take into account the social and political aspects of engineering and scientific problems—in short, men and women who can be "engineering statesmen."

This is to my mind the greatest problem facing the engineering colleges today, and it confronts them just at the time when they face a host of other urgent problems resulting from wartime deferment policies and the present and prospective rush of students, veterans and non-veterans, to college.

The A.S.E.E. study on "The Outlook in the Demands for and Supply of Engineering Graduates" indicates a great current shortage of engineers and a demand for them beyond the ability of the engineering colleges to supply for several years to come, after which there is indicated a levelling off in the demand at a figure about 50 per cent above the supply during the last few pre-war years.

* Presented at a meeting of the New England Section, A.S.E.E., at Norwich University, October 5, 1946.

The Veterans Administration reports that as of August 31, 1946, 4.2 million veterans had applied for training benefits under Public Laws 16 and 346, and that applications through the summer months were at the rate of 400,000 per month. There were 1¼ million veterans in training on August 31, 1946, and ½ million had terminated training. The largest enrollments of veterans on August 31 were in liberal arts, with engineering second. However the liberal arts enrollments include pre-professional students, many of whom will be engineers. The Veterans Administration also reports a great interest in the two-year terminal courses offered by technical institutes, which in some instances are closely associated with engineering schools and in any case are of great interest to them and of great importance to industry.

It is predicted by some competent observers that by 1949–50 there will be more than 2 million veterans in training at one time, of whom something over 1 million will be in college.

It may be of interest to list a few of the important problems now facing higher education in general, and engineering education in particular, without attempting at present to find their solutions.

What should be the basis for selection of students? Most engineering colleges are compelled by limitations of staff and facilities to admit only a portion of those who apply. Should selection be predicated on residence, or war service, or race, or creed, or on ability to profit from an engineering education? Should it be based on a paper record of credits earned, or on mastery of necessary foundation subjects, no matter how gained? Many believe that a well organized testing program is a better indicator of success in college than a high school record several years old.

What sort of guidance should be given to veterans and others as to their future occupations, and by whom? Many agencies are trying to help in this important matter. Veterans receiving training under PL 16 must receive guidance from Veterans Administration counselors—others may avail themselves of it if they wish. Many other organizations, local, state, and national, are trying to help. Surely a grave responsibility rests on the engineering colleges, in view of the public interest in engineering engendered by war time developments and experiences, because of the numbers of veterans, both qualified and unqualified, seeking to be engineers, and because of the great need of industry for *competent* engineers.

What sort of curricula and instruction should engineering colleges offer their students? Should they attempt to *train* for the rank and file of engineering jobs, or to *educate* for leadership in industry, teaching, and research? Should they put the major emphasis on vocational training or on the development of personal and social characteristics?

What changes in traditional courses and teaching methods are indicated by the presence of the large numbers of veterans in the engineering colleges? These veterans are older than the typical high-school graduate, they have a much more adult attitude, a more serious purpose, and a much greater urge for *speed* in preparing for their life-work. Does this mean they should be given E.S.M.W.T. *training?* Or should some of the techniques developed in E.S.M.W.T. courses be used to revitalize and intensify engineering *education?*

What kind of teachers do the engineering colleges need, and how can they be recruited? Must the colleges lower their standards because of their tremendous need for teachers and the competition of industry and government? Selective Service has recently adopted a policy of deferring college teachers still left in the age groups subject to the draft, which may indicate the possibility that a national overall manpower program may be developed. Can this possibility be made a reality? Can programs be developed to train engineers to teach? Can industry and education work out some sort of a cooperative system for teachers, as they have done so successfully for students?

What sort of relations should there be between higher education and the Federal Government? Should there be a program of Federal aid to education? If so, should it be extended to individual students or to institutions, or both? Should it be extended only during the present emergency, or permanently? If to institutions, should it be extended only to tax-supported institutions, or should the privately supported tax-exempt institutions share in it? The Federal Government is now aiding individuals through the GI bill and PL 16. Legislation has been proposed setting up a system of Federal scholarships. Institutions, both public and private, are being aided through the veterans housing program and the Veterans Educational Facilities program in the acquisition of temporary buildings and equipment. A bill to establish a program of Federal aid in the erection of permanent buildings was debated in the last session of Congress. How far should efforts to meet an emergency be allowed to color permanent policies? In this country education has traditionally been considered a function of the states. Should the base be now broadened by making it at least partly a function of the Federal Government? If so, should Federal funds be used to partially equalize educational opportunities in the various states?

These problems represent only a partial list of the vital problems facing engineering colleges (and all colleges)—problems whose solutions will call for the highest type of "engineering-educational-statesmanship." It must be evident to all that for higher education the "good old days" are gone forever. The colleges can't turn back, even if they want to, to the easy schedules, the long vacations, the dealing with immature minds, which characterized the college of pre-war days. They *must* go ahead, they *must* find solutions to the new problems facing them, they *must* use to the utmost such courage and such vision as they possess, or our country's battle to win the peace will be lost.

The President of the United States, recognizing the seriousness and complexity of the problems facing higher education, has appointed a Commission on Higher Education which is making an effort to measure national educational needs on a long range basis (through 1960 or thereabouts), to form the foundation for a determination as to what the colleges should do. Studies assigned to sub-committees at the first meeting of the Commission were:

The Responsibilities of Higher Education in Our Democracy and in International Affairs.

Ways and Means of Providing Higher Educational Opportunity to All in Terms of the Needs of the Individual and of the Nation.

The Organization and Expansion of Higher Education.

Financing Higher Education.
Providing Personnel for Higher Education.

What part can the Office of Education play in the battle to win the peace? What should be the relationship between the Office of Education and the colleges; between Federal and state educational agencies? The basic act passed by Congress in 1867 establishing the Office of Education authorizes it to collect statistics and facts showing the condition and progress of education and "to diffuse such information respecting the organization and management of schools and school systems, and methods of teaching, as shall aid the people of the United States in the establishment and maintenance of efficient school systems, and otherwise promote the cause of education throughout the country."

In discharging these responsibilities the Office of Education is maintaining several continuing activities which it may be of interest to outline briefly.

The Office of Education is certifying to Selective Service the names of college teachers who are essential for the conduct of the programs of their institutions. Under recent directives of the Office of War Mobilization and Reconversion the National Headquarters of Selective Service will recommend to local boards that teachers so certified be deferred. Final action, of course, still rests with the local boards, and there is no blanket deferment for teachers. Each case is considered individually on the basis of information submitted to the Office of Education by the institution on Selective Service Form 42A (Special) (Revised). It is important that in filling out this form complete information about the duties of the teacher be given, so that prompt action may be taken.

The Division of Surplus Property Utilization in the Office is working closely with the War Assets Administration and with the Army and Navy in assisting the schools and colleges to secure both real and personal property made available by these agencies.

The Office of Education administers the Federal funds annually made available to the land grant colleges. The Office initiates the annual certification to the Secretary of the Treasury for the payment of funds to the colleges, collects annual reports from them, prepares a summary statistical report on the institutions, and obtains legal interpretations when questions arise with respect to the use of these Federal funds.

The Office of Education will upon request certify the credentials of American students who are going to foreign countries for study or for employment, and will evaluate the credentials of foreign students seking admission to American colleges and universities.

The Office endeavors to maintain contacts with other Federal agencies and is frequently in a position to assist colleges and universities with problems involving these agencies.

A considerable amount of correspondence reaches the Office calling for consulting services by various Divisions of the Office, and a very large amount of correspondence is answered from prospective students seeking information as to the offerings of colleges and universities.

The Division of Higher Education publishes a bi-monthly bulletin called "Higher Education" which is sent to all college and university presidents, deans of liberal arts, deans of engineering, and others. This bulletin contains brief articles of general interest to higher education, news items, and an-

nouncements of publications of interest to higher education. One recent article concerned the S.P.E.E. (now A.S.E.E.) summer school conducted at Washington University last summer.

The Office publishes an Annual Report describing the activities of its various divisions, and an annual Educational Directory, of which Part III is a listing of all accredited colleges and universities in the country and their principal administrative and academic officers, and Part IV is a listing of Educational Associations and Directories, with names and addresses of principal officers. A recent change in policy permits the indication in the next issue of the directory, now in press, that certain institutions are accredited by E.C.P.D. although they have no official who holds the title "Dean of Engineering." Former editions of the directory contained no indication that these institutions offered any courses in engineering.

The Office publishes at intervals a listing of Accredited Higher Institutions in which are outlined the methods of accreditation, the agencies performing it, and the accreditation given to each institution. Part I of the list covers universities, colleges, junior colleges, and teacher training institutions, and Part II covers professional and technical schools. This bulletin, as well as the annual directory, is in large demand from educators and state and Federal agencies.

Beginning in 1918 the Office has published biennial surveys giving Statistics of Higher Education. Publication has been interrupted during the war but is being resumed this fall in a slightly modified form. This bulletin has also been in large demand.

The Office publishes special bulletins giving the results of studies by staff members and others. Recent examples of these special bulletins are the histories of the war training programs, and a study of vocational education of college grade, all of which are now in press. Copies of these and other publications of the Office will be sent on request. Staff members of the Office serve on various professional committees and attend meetings of professional and educational associations for purposes of liaison with the associations. A recent example was the conference on "Emergency Problems in Higher Education" conducted under the auspices of the American Council on Education, in which several members of the staff participated. Another recent example consisted of participation on an inter-agency committee on disposal of Federal property for educational purposes, which was sponsored by the Retraining and Reemployment Administration of the Department of Labor. The work of this committee resulted in the publication of a pamphlet of information for educational institutions, designed to inform them which agency to contact and how to do so with respect to the acquisition of various kinds of Federal property. This pamphlet is not intended to be a complete detailed manual of procedures, but is intended to help the institution to "get its foot on the first rung of the proper ladder."

So much for the general activities of the Office of Education. Specifically, what can I, as the Specialist in Engineering, do to help the engineering colleges? First of all, I am quite certain that neither I nor the entire staff of the Office of Education can give the colleges the solutions to all their problems. But I should be able to be of some assistance to them in arriving at their own solutions, if they will call on me. Second, there is no desire on the

part of any member of the staff to attempt to issue directives or instructions to the colleges. Rather, it is our hope that the colleges will tell us when, where, and how we may be able to help them.

It seems that there should be a field of usefulness for the Office of Education in helping, or possibly even taking the lead, in national studies of various problems in engineering education. For example, I was grateful for the opportunity given me last spring to contribute to the S.P.E.E. study on supply of and demand for engineers. I plan to prepare with Dr. Bishop's help a "follow-up" on that study for the Engineering Section of the Land Grant College Association in December. I shall welcome suggestions as to useful studies at any time and hope to have the help of the colleges in their conduct. I shall of course be careful not to interfere with or to duplicate the activities of A.S.E.E., E.C.P.D., or other established groups, with which I desire to cooperate as fully as possible.

In my dealings with the colleges I shall follow one of the basic principles of E.S.M.W.T.—that of maintaining direct contact with each college individually, with no intervening agency. I am happy to say that in almost every engineering college the dean has designated some individual (in most cases himself) as the official liaison officer between his institution and our office. I believe that these contacts can be mutually helpful—I know they are helpful to me, and I have already been privileged to perform some direct services to a few colleges. I shall endeavor to keep the colleges informed of important developments in Washington, and I hope the colleges will keep me informed of their activities, and will let me know when I can help with specific problems.

One of my concerns has been with ways and means of aiding the colleges in their search for teachers. Following discussions with officials of the National Roster of Scientific and Specialized Personnel it was decided to expand its services to the colleges in locating teachers. The Roster had previously limited this service to screening the records of registrants who had indicated that they were available for employment. This spring the Roster decided that for major positions such as full professors and department heads they would screen the records of all registrants in the professional field involved. The Chief of the Research Section of the Roster reports that up to October first the Roster had been asked to aid in filling 1,371 college vacancies and had referred the records of 3,500 registrants, of whom about 25 per cent were engineers.

Late in July I sent a memorandum to the deans of engineering telling of a possible source of engineering and science teachers in the technical and scientific personnel being released from the Navy. Arrangements had been made with the Director of Scientific Personnel Division to allow college representatives to examine the records of these people. The Director informs me that up to October first 32 colleges had sent representatives to his office, who had taken 750 names from the files with the intention of offering employment to each. Unfortunately the institutions have in general not reported as to the actual employment of these people, and we are therefore unable to make any definite statement other than that a good many of them have been employed by colleges.

I have been appointed Director of

the Student War Loans program, which made loans to some 11,000 students during the war—(a large number of whom were engineering students) to enable them to complete their education. No loans are now being made, but extensions of time for repayment, and cancellations of loans under certain circumstances, require in some instances administrative decisions, often following rather lengthy investigations. The routine operations of collecting loans are handled by a small clerical staff under my general supervision.

I started early this summer a series of short bulletins to be published at irregular intervals to advise the engineering colleges of activities of Federal agencies which, in my opinion, would be of special interest to them. Two bulletins were issued, one outlining the distribution of O.S.R.D. reports to libraries and one telling about a possible source of teachers in persons being released from the Navy. These bulletins were issued late in July and none have been issued since that time because of my assignment by the Commissioner of Education to the Veterans Educational Facilities Program which was set up to implement Public Law 697 (the Mead Bill).

When it semed likely that the Mead Bill might pass, the Commissioner assigned to me the duty of laying preliminary plans for discharging the duties assigned to him under the Bill. In cooperation with the officials of the Federal Works Agency who would be in charge of the program, an administrative organization was outlined using the principles of decentralization, delegation of authority, and direct contacts with educational institutions which proved so successful in conducting the E.S.M.W.T. program. Immediately after the passage of the bill, E. V. Hollis, Specialist in Statewide Programs, was designated as the Director of the new program and I was designated as Associate Director. We have been devoting practically our entire time to it since then.

Public Law 697 authorizes the Federal Works Agency to furnish buildings and equipment to educational institutions in which the Commissioner of Education certifies that urgent shortages exist or are imminent in such facilities needed for the education of veterans. This means that F.W.A. cannot act on a request from an institution until the Commissioner, or his representative, has certified an educational need. It means further that the Finding of Need by the Commissioner's representative establishes a ceiling beyond which F.W.A. cannot go in aiding an institution. F.W.A. can furnish only such facilities as it can secure from Federal surpluses, with the approval of the War Assets Administration.

F.W.A.'s operations are decentralized and conducted through nine Divisional offices. In order to expedite the program we, therefore, similarly decentralized the operations of the Office of Education in the program. We have established in each F.W.A. Divisional office a Chief Educational Officer with whom will be associated other Educational Officers. These men have power to act for the Commissioner in approving Justifications of Need submitted by schools and colleges in the states constituting the Division. They deal directly with individual institutions, just as the Principal Specialists in the E.S.M.W.T. program did, looking to the Washington staff only for general policies and criteria. They submit to the F.W.A. Division Engineer a Finding of Need based on their study of the Justification of Need submitted by

an institution. F.W.A. will then accept formal application from the institution for such items in the Finding of Need as it feels able to supply at the time, leaving the way open for later applications for other items included in the Finding of Need.

We believe that this type of organization and procedure will enable F.W.A. to supply needed facilities to the colleges as expeditiously as possible, and we have received from colleges and universities many expressions of satisfaction with this arrangement.

F.W.A. has set up tentative allotments of funds by states in accordance with the number of veterans certified for training in each state, which will insure an equitable distribution of funds among the various states. They have set up even more tentative allotments to institutions within a state to serve as rough guides for their engineers in the acceptance of applications from institutions. It therefore is much more important that an institution submit a carefully written and thoroughly documented Justification of Need than it is for it to be among the first in a state to submit a Justification.

Shortly before I left Washington the Civilian Production Administration issued Direction 23 to Priorities Regulation 13, under which educational institutions are given first priority, except for items which may be needed under the C.P.A. and N.H.A. housing programs, on certain categories of educational equipment which are listed in the Direction, provided their orders have been certified by Federal Works Agency as necessary to enable the educational institution to meet the requirements of the veterans' educational program. The War Assets Administration Order 6 under Regulation 14, which implements C.P.A. Direction 23, establishes the sales price for items in the specified categories as five per cent of the "fair value," the institution being required to pay transportation costs.

F.W.A. has announced that it will certify orders under this program only for those institutions for which a Finding of Need covering the items ordered has been submitted by the representative of the Commissioner of Education. The Justification of Need on which such a Finding of Need is based may also include requests for buildings and for items of equipment not specified in C.P.A. Direction 23. It should in fact include all educational facilities needed by the institution in its program of educating or training veterans under Public Law 346.

The decision as to whether specific items of equipment are to be secured by F.W.A.'s Bureau of Community Facilities under regular V.E.F.P. procedures, or by the institution following procedures of the program under C.P.A. Direction 23, will be made by the institution in consultation with the F.W.A. Division Engineer.

The program under C.P.A. Direction 23 greatly improves the chances of educational institutions securing equipment included in the specified categories, provided they can justify their need in terms of the provision of education to veterans. It seems likely that this new channel offers the best opportunity thus far afforded educational institutions to secure equipment in these specific categories. The colleges may rest assured that the Office of Education and the Federal Works Agency will use every effort to make these new programs as effective as possible in aiding them to secure the buildings and equipment which they need in order to carry out their veter-

ans educational program in such a way as to benefit the greatest possible number of veterans. If other categories of equipment and supplies become available to educational institutions through amendments to the existing C.P.A. Directions and W.A.A. Orders, the schools and colleges will be promptly notified.

I know that I speak for the Office of Education, and particularly for the staff of the Division of Higher Education, when I say that we are anxious to do whatever we can, with our quite limited staff and funds, to assist the colleges in the solution of their problems, and to "promote the cause of education throughout the country."

As for myself, I like to feel that I am in effect an unofficial representative of the engineering colleges in Washington—a "friend at court," anxious to help the cause of engineering education in any way that I can. I am attempting to develop contacts and sources of information of value to engineering educators. I hope you and your institutions and your societies will call on me whenever you feel that I or the Office can help you. I may not always be able to help you, but I can and will *try* to help.

Notes on the Philosophy of Stress Analysis

By L. T. WYLY

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The principal purpose of a college education is to assist the student to develop the capacity for independent work. Perhaps the main qualification for such original work in engineering is intellectual power in logical analysis. Since it is desirable that both instructor and student keep this objective constantly in mind, attention may be directed to the philosophy underlying analytical procedures.

Steps in Analysis

In any given situation there are certain required values, unknown at the start, whose determination constitutes the object of the inquiry. The essential steps in the analysis are the following:

1. The relations between the various unknowns are expressed in terms of the principles or theorems of the laws of theoretical mechanics. The mathematical statements of these relations constitute the equations.
2. Each equation, being an application of a principle of mechanics to a specific case, must be accurate and complete in itself. The units and signs used pertain to the principle selected and must be correct and consistent with that principle, and with the conditions of the structure.
3. When as many independent equations as there are unknowns have been properly set up and solved, either simultaneously or by successive approximations, the true values of the unknowns have been found.

Illustration

An illustration of a suggested method of procedure, with respect to both intellectual sequences and method of showing the work on paper, is given in Fig. 2. This illustration emphasizes the three steps enumerated above.

Signs

It is suggested that most of the difficulty which sometimes arises in connection with analytical work comes from failure to follow out the above philosophy logically and completely. One of the most common sources of confusion is the matter of algebraic signs, and a few remarks may be directed to this subject.

Signs are used to denote relative direction. If all forces acting on a given body acted in the same direction, or if all moments tended to rotate the body in the same direction, all signs would be positive.

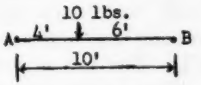
It is thus plain that sign conventions are a matter of convenience and that they are not sacred. In any given case the convention most convenient to the investigator should be used. In certain matters, such as the external shear acting on a beam, the sign conventions

are identical all over the world, both by common consent and by custom. In other cases, such as the sign of bending moments, the conventions adopted depend on the purpose for which the bending moment is used, as well as on the preference of the investigator.

Rules governing the use of signs may be arrived at by consideration of the simple problem presented in Fig. 1.

GIVEN : Beam and Loads Shown

REQUIRED : Vertical Reactions at Supports A & B



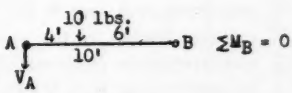
CONDITIONS USED (1) $\Sigma M_B = 0$
(2) $\Sigma V = 0$

Direction of reactions V_A and V_B theoretically unknown and assumed positive.

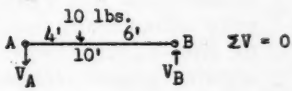
SIGN CONVENTION ASSUMED Moment ↻ +
Force ↑ +

A. CORRECT PROCEDURE

EQUATIONS (1) $6(10) + 10\ V_A = 0$



(2) $-10 - V_A + V_B = 0$



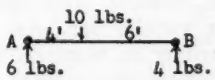
SOLVING (1) and (2)

(1) $V_A = -6$

(2) $-10 - (-6) + V_A = 0$

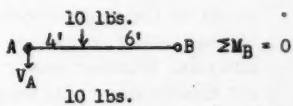
$V_B = +4$

COMPLETED LOADING DIAGRAM CORRECT

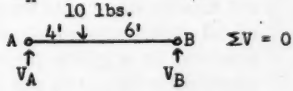


B. INCORRECT PROCEDURE

EQUATIONS (1) $6(10) + 10\ V_A = 0$



(2) $-10 + V_A + V_B = 0$



SOLVING (1) and (2)

(1) $V_A = -6$

(2) $-10 + (-6) + V_B = 0$

$V_B = 16$

COMPLETED LOADING DIAGRAM INCORRECT

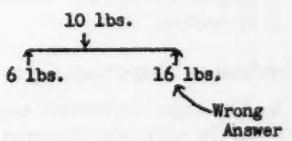


FIG. 1. Study of sign procedure.

COMMENTS ON FIG. 1

Principles Used: The principles of mechanics used are the conditions of static equilibrium. Obviously a number of other theorems or principles could have been used but probably less conveniently.

Equation (1): This is a moment equation. Signs used refer to direction of moments about moment center B.

Equation (2): This is a force equation. Signs used refer to direction of forces.

Sign Procedure: The direction of the reactions at A and B are theoretically unknown at the start. If a positive value is *assumed* for the moment about B of V_A the investigator automatically assumes that the force V_A acts downward. The negative answer obtained shows that this assumption was incorrect and the true direction is upward.

Caution: It is very important, however, to note that when a direction of a force, moment, joint rotation or other variable has been assumed in writing an equation, the force or moment, etc., must be assumed to act in the same direction when writing other equations for the analysis. In other words, one may not blindly write plus for the signs of all unknowns in all equations involved in a given problem and confidently expect to get a correct solution. Since this is precisely where many students go wrong, the fallacy is illustrated in the example, *incorrectly* worked in B procedure.

Conclusions Regarding Signs.

1. The sign convention used refers to the particular theorem or principle of mechanics used in setting up the equation in question. If the variables are expressed in terms of joint rotation, the signs refer to direction of rotation. If the variables are expressed in terms of work done, the signs refer to work.
2. When a sign is assumed for the direction of an unknown in writing an equation, the investigator automatically assigns to the unknown force, moment or other variable involved a direction, and this force, moment or other variable must then be assumed to act in this same direction in setting up remaining equations for the same problem.
3. Subject to the above restrictions, any desired convention of signs may be assumed by the investigator.
4. Procedure Rules.
   (a) If the signs of the unknowns in the basic equations are correctly assumed the answers will come out positive.
   (b) If the signs of the unknowns in the basic equations are incorrectly assumed the answers will come out negative.
   (c) If the signs of the unknowns in the basic equations are all assumed positive the answers will be correct in sign.
   (d) When writing an equilibrium equation it is desirable to place the summation of moments, forces, etc., on one side of the equality sign and the zero on the other side. Similar reasoning applies to other equations.
5. The above conclusions are perfectly general.

MOMENT AREA METHOD
EI Constant
Loading Diagram
Distortion Diagram
Moment Diagram
Shear Diagram
REQUIRED: M_A, M_B
CONDITION EQUATIONS
(1) $\theta_B = \int_A^B \frac{M dx}{EI} = \frac{t_{BB}}{L}$
(2) $2(M_A+M_B) = Fh$
EQUATIONS
(1) $\frac{t_{BB}}{L} = \frac{M_B L}{2}\left(\frac{2L}{3} - \frac{L}{3}\right) \div L = \frac{M_B L}{6}$
$\int_A^B \frac{M dx}{EI} = \frac{M_A h}{2} - \frac{M_B h}{2}$
$\frac{M_B L}{6} = \frac{M_A h}{2} - \frac{M_B h}{2}$
or $M_A = M_B \frac{(L+3h)}{3h}$ (1)
(2) $M_A + M_B = \frac{Fh}{2}$ (2)
$M_A = \frac{Fh}{2} \cdot \frac{(L+3h)}{(L+6h)}$
$M_B = \frac{Fh}{2} \cdot \frac{3h}{(L+6h)}$
$V_{AB} = \frac{M_A+M_B}{h} = \frac{F}{2}$
$V_{BB} = \frac{M_B+M_B}{L} = \frac{F}{2}\frac{2h^2}{L(L+6h)}$
Sign Convention θ ↻ +
M_B at left increases θ_B Sign taken +
M_B at right reduces θ_B Sign taken -
M_A increases θ_B Sign taken +
M_B reduces θ_B Sign taken -
M_A and M_B each resist bending. Signs taken +
Sign Convention M ↺ +

SOLVING
Solving Condition Equations (1) and (2) the values for M_A and M_B are obtained.

FIG. 2. Analysis of Portal Frame.

Comments on Fig. 2.

Principles Used: Condition Equation (1) is a statement of the geometry of the distorted frame and is based on the two theorems of the Moment-Area method.

Condition Equation (2) is a statement of the stability of the unbraced members AB under the bending moments induced by force F acting through distance h.

Equation (1): Signs of all four bending moments are determined by the effect these moments have on the angle θ_B and by nothing else. Note that θ_B for AB has the same direction and hence the same sign as θ_B for BB, since joint B is assumed to be rigid and the value of each angle is the same as the other. Note also that the verticals are assumed fixed against rotation as well as against displacement at A. Stresses produced by M_A tend to rotate the tangent at B in a clockwise direction while the stresses produced by M_B tend to rotate the tangent at B in the opposite direction. The signs of these two moments must be opposite in this equation. A similar reasoning controls the signs of the moments on BB.

Equation (2): Since the verticals resist the transverse force F by bending both at top and at bottom, these moments must have like signs for this equation. No other considerations enter into this selection of signs here.

Comments on other Sign Applications

The rules and principles listed above apply to all distortion problems, whether geometry or energy be used.

Where an equilibrium equation is written for all moments at ends of members entering a joint, equilibrium against joint rotation is the governing factor in sign determination. See Fig. 3(a).

The Slope-Deflection equations express the end moments of a member in terms of joint rotations θ, and member rotations Δ/L. These angles θ and Δ/L are thus usually the unknowns. When writing the equation for bending moment at the end of a member by this method, the signs of joint rotations in a given direction must be taken opposite to the signs of member rotations in the same direction, since these two effects induce end moments in the member which tend to rotate the joint in opposite directions. See Fig. 3(b).

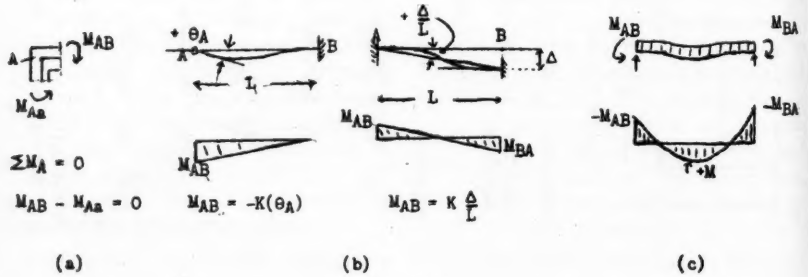


Fig. 3.

From the standpoint of proportioning material in beams after the stresses have been determined it is convenient to call the moments producing tension on one side positive, while those which produce tension on the opposite side are called negative. See Fig. 3(c).

Where a given operation is carried out repeatedly without changing conditions, specific rules for signs may be arrived at. It is, however, never safe to follow such rules blindly nor to carry them over to conditions to which they may not apply.

Conclusion

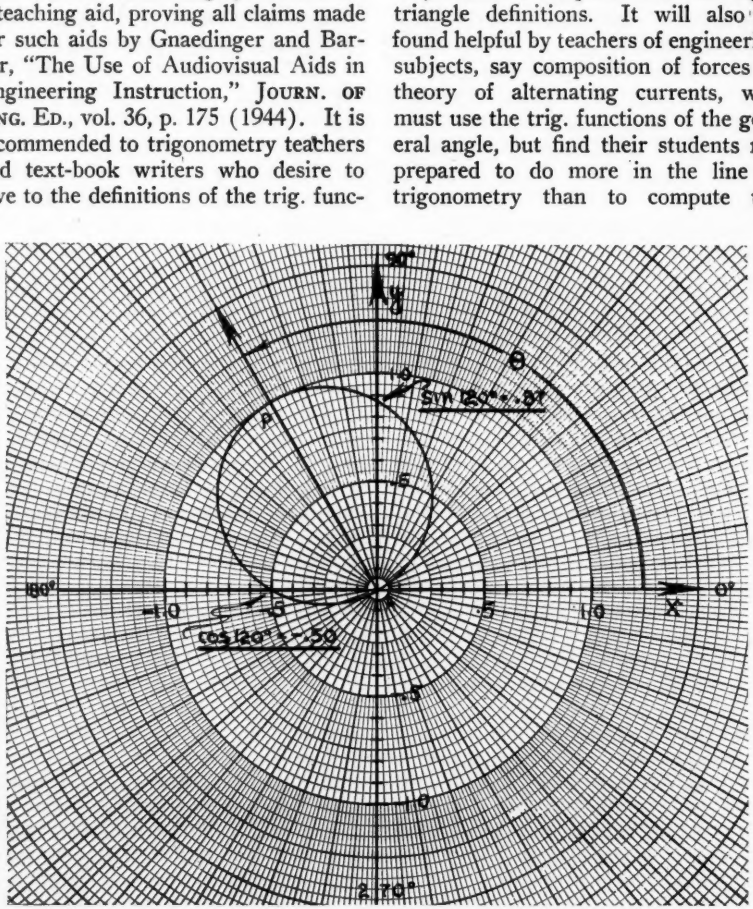
Since it is necessary that the problems presented in the analysis of a structure or unit be thought through in accordance with the principles and rules stated in this paper, it is desirable that the written solution be so organized as to show the steps taken and the conventions used. In the writer's estimation attention to this matter should start when the student is introduced to the subject of mechanics for the first time, and such attention should continue throughout the college course.

Projections of a Rotating Vector

By I. F. RITTER

Assistant Professor of Mathematics, New York University

The simple device described in this note has been found highly effective as a teaching aid, proving all claims made for such aids by Gnaedinger and Barker, "The Use of Audiovisual Aids in Engineering Instruction," JOURN. OF ENG. ED., vol. 36, p. 175 (1944). It is recommended to trigonometry teachers and text-book writers who desire to give to the definitions of the trig. functions of the general angle the emphasis they deserve, compared with the right triangle definitions. It will also be found helpful by teachers of engineering subjects, say composition of forces or theory of alternating currents, who must use the trig. functions of the general angle, but find their students not prepared to do more in the line of trigonometry than to compute the



height of a flagpole from a right triangle. The latter situation, encountered in a refresher course given to the technicians of a large radio station, led to the design of the device.

To gain the full advantage of this device, the student should make it himself thus: On a sheet of polar graph paper lay out a scale from 0 to 1.0, running from the pole along the 0° ray and along the 90° ray, and similarly a scale from 0 to − 1.0, running from the pole along the 180° and along the 270° rays. On a sheet of transparent material (tracing paper or, much better, cellophane or another plastic) draw a circle with diameter equal to one unit of the scale used on the polar graph sheet. Draw the diameter AP of this circle. Put a pin through A, and through the pole of the graph sheet, into a drawing board, so that AP becomes a rotating unit vector in the polar coordinate system. Then on the x-axis, formed by the 0° and 180° rays, read $x = \cos\theta$ and on the y-axis, 90° and 270° rays, read $y = \sin\theta$, for angles θ through all quadrants.

This is, of course, the line-value definition of these functions for the general angle. However the use of the device, preferably preceding the use of tables, to compute components and resultant of a number of vectors pointing into various quadrants, will help the student to comprehend the definition, and familiarize him with the signs and magnitude, of these functions in all quadrants. This is otherwise usually achieved only after using coordinates in a course in analytic geometry. By using the device to plot graphs of the trig. functions the student is made aware of, for instance, the continuous variation of $\sin\theta$ and $\cos\theta$. If the vector AP rotates with constant angular velocity the student can also see the simple harmonic motions performed by the projections of P on the axes.

Coordination of Teaching in Physics and Engineering Mechanics

By W. H. MICHENER

Carnegie Institute of Technology

This paper will not be mentioned in the headlines. It will not even make a front page story. To receive wide attention, one must propose sweeping changes—changes in curriculum or changes in teaching methods. I have nothing which is startlingly new to offer. The important things which I have to say may be well known, but they need to be repeated.

Good teaching—whether it be in mechanics or physics, or in history—depends primarily upon having good teachers. But how do we get or make good teachers? There is no simple answer to this question. But one of the prime requirements is interest—interest in the subject, interest in the students, and interest in the problems of teaching. This interest may be developed and maintained if there is the proper attitude on the part of the teacher's colleagues and particularly of his superiors.

You may expect good teaching in a compact department where there are frequent meetings—either formal or informal—to discuss teaching problems. The young instructor should have the responsibility of developing his own methods, but he should not be left without guidance. In times like these, when there are likely to be large numbers of new instructors, there should be some formal plan of tutelage by an experienced instructor.

These procedures for improving teaching would seem to be in the hands of the instructional staff. But they can hardly succeed without the cooperation of the administration—department heads, deans, and presidents. If recognition and advancement is given only to those who, in addition to being passable teachers, are doing research and publishing papers, then the teaching will remain only passable. In making this statement I do not wish in any way to belittle the importance of research. But I repeat, the good teacher must have interest not only in his subject but also in his students and in the problems of teaching. And part of the responsibility for maintaining these interests lies with those who employ instructors and give or recommend promotions.

Now that I have said the important things, let us proceed to some of the details which are suggested by the title. I will recount some personal experiences in cooperation between departments of physics and mechanics. It has been my good fortune to be in a school where teaching was not just a side line. These incidents occurred a decade ago. The turmoil of war has changed many of our activities. At

the time of which I speak our department of physics and the department of mechanics were each compact units. We in the physics department were sure we knew how to teach physics; and, of course, we were also sure we knew many things that were wrong with the way mechanics was taught in the other department. They likewise knew much that was wrong with our teaching of physics, but they were polite enough not to tell us to our faces. This kind of situation may not be entirely unfamiliar to you.

With this as a background, a few meetings were held for the combined staffs of the two departments. Needless to say, many of our differences vanished, others were seen to be less important than we had thought, and some differences still remain. The important outcome of such meetings is that each of us sees the problems of the other a little more clearly. We find that we are working together for the same purposes. We are not so likely to say to a student, "I don't care how they do it in mechanics (or in physics), but here is the right way."

Some of the shortcomings or faults of the instruction in physics as seen by the department of mechanics are as follows. Students do not know how to analyze the forces acting *on* a body and draw a "free body diagram." Students show evidence of having worked problems, but apparently without a clear understanding. Now we instructors in physics know we have never overlooked the importance of such fundamentals. But nevertheless since that time I have always put more stress on the analysis of the forces acting on a body, and correspondingly less emphasis on complete numerical solutions. The student, in explaining even the simplest problem before the class, is required to identify or isolate the body upon which the forces act. He must then indicate all the forces acting *on* the body; and finally, he must draw a separate vector diagram apart from the figure illustrating the problem. This last requirement is violated far too often in physics textbooks, and the student is misled to believe that the length of a string is related to the magnitude of a force.

Instructors in mechanics also find that we have not sufficiently emphasized action and reaction, and the relation of internal and external forces. Perhaps we don't. At least we agree that they should be emphasized.

The equation $L = I\alpha$ is more dangerous than some of us realized. Students are not sufficiently warned in physics of the limitations of this equation. If we teach it at all we should point out that it applies only to a rigid body, and in general only to rotation about a fixed axis. Perhaps the physics instructor should introduce the student to some problems in which the equation cannot be used. It is well for the student to realize that there is more for him to learn in some later course.

We are accused by the mechanics department of doing a very poor job of instruction on centripetal force, and shall I say, centrifugal force. I cannot admit that I personally am at fault in this respect, and no doubt each of you has the same conviction about your own teaching of the subject. But perhaps we have seen diagrams in some physics texts which could easily mislead the student into believing that there is a force, mv^2/r, acting *on* a body *away* from the center of rotation. This brings us back to the importance of teaching a student to analyze the forces acting *on* a body. For example, a stone, on a string, moving in a horizontal circle at constant speed is acted upon by two

forces. One is the force of gravity and the other is the force of the string. There can be no other forces on the stone if there is nothing else touching it, and we may neglect the force of the air. The resultant of these two forces is directed toward the center of the circle—not away from the center. The stone, moreover, is not in equilibrium. It has an acceleration in the direction of the resultant force. The use of d'Alembert's Principle should, in my opinion, not be introduced in elementary physics.

The foregoing examples are some of the things we can learn from the teachers of mechanics. Now what can they learn from us? In the first place they should realize the limitations on our accomplishments in teaching. Even under our "expert" guidance, students will not acquire a complete understanding of basic principles in the few weeks which we may devote to mechanics. The mechanics instructor should not disregard what has been taught in physics, nor should he assume that these basic principles have been mastered. Instruction in engineering mechanics should be directed toward increasing the depth and breadth of the foundation, and not merely in building a superstructure of applications on top of a weak foundation. The process of education should involve going deeper as well as higher in each succeeding course of instruction. A high school course in physics is necessarily more superficial and may cover a wider range of topics than a course in engineering physics. There should be emphasis on fundamentals at every stage of instruction, but it is not possible, with human beings as they are, to insist on a mastery of all these fundamentals in the first courses. In these earlier courses the student is almost certain to acquire some misconceptions, or learn some things which are not true. No matter how hard we try, this cannot be entirely avoided. But it does not follow that the earlier courses do more harm than good, as has sometimes been stated.

We sometime accuse the mechanics department of placing too much emphasis upon the working of problems. Too much of the student's time is spent on routine calculations. To pass an examination the student merely acquires dexterity in manipulating numbers and obtaining answers to type problems. This criticism is often directed against the teaching of physics also, and possibly with equal justification. We are too prone to assume that, because a student can work a problem, he understands the principles involved. Tests and examinations are worthy of much more study than we give them. Students—even good ones—will direct their energies toward passing the kind of examinations which are given. If these consist merely of type problems, then the student will spend his time learning to solve problems, regardless of how much emphasis the instructor in class may place upon the basic principles.

The question of units is one upon which I see no hope of agreement between the departments of mechanics and physics, or even among instructors of physics themselves. As a practical matter I think we must use two or three different systems of units in physics. I would prefer that this procedure be continued in mechanics. The student would profit much more by our instruction on systems of units if this instruction were continued in the mechanics department. We find too many students who, after studying mechanics, know only that they should divide weight by 32 to get mass.

And now that I have mentioned mass

I am sure that those of you who know me well realize that I cannot go on without making some further remarks on the subject. I know of no topic in general physics which is more generally mistreated or obscured in text books. To say that mass is a quantity of matter is much worse than meaningless. Mass, as the term is actually used in mechanics, is the property of a body. It is that property which is more popularly known as inertia. It can and should be clearly defined. It is scarcely more difficult to define what we mean in saying that the mass of a body is 10 lb, than it is to define what we mean in saying the length of an object is 10 ft. Neither of these definitions can be given well in one sentence. While we may properly speak of "the mass of a body," it is just as improper to call this body either "a mass" or "a weight" as it is to call it a length. But I must not get started on this subject or we would need another day.

Let me now summarize what I think is important for the improvement of teaching in mechanics and physics. I do not propose radical changes, nor do I think a complete blueprint is desirable. The greatest improvement will come by continued discussions among all those who are teaching the two subjects. It is not necessary to strive too hard for agreement but rather each individual should try to see the point of view of the other. The benefits will result from the increased understanding whether or not there is complete agreement. No one should feel compelled to accept the other's conclusions. Good teaching seldom results from compulsion.

Finally, if you are a department head or an administrator, the greatest thing you can do is to give recognition and encouragement to the instructor who is taking an interest in teaching, and to see that there are plans whereby the new instructors receive help and advice from those of longer experience.

Discussion

By J. G. POTTER

A. & M. College of Texas

In considering the papers which have been presented, the most significant aspect is the absence of any real division of opinion or division on mode of procedure between the teachers of physics and the teachers of engineering mechanics. The case of d'Alembert's Principle is an especially good example. Both Professor Williams and Professor Michener independently singled this out as a concept to be avoided in elementary mechanics. Although I know of one general physics text used in a fair number of colleges which handles problems in dynamics from the point of view suggested by d'Alembert, my observation has been that most physics teachers regard this as poor pedagogy, and the representative of the publisher of the book told me recently that this is always the first point raised by physics teachers in objecting to the book. From Professor Williams' most effectual discussion of the disadvantage of obscuring the Newtonian concept of acceleration in the presence of an unbalanced force by the d'Alembertian concept of an equilibrium between this force and an imaginary kinetic reaction, one might suspect that

he was accusing the physicists of this misdemeanor in pedagogy. However, I know on my own campus the physics department has been disturbed to find that it is the mechanics department which has been teaching the d'Alembert concept.

Since we now see that this is a point of view which both departments find leads to trouble, allow the speaker to add his thrust at the concept. We try to build up an ideology based on Newton's second law to the effect that acceleration of a body always results when the vector sum of all the forces impressed on that body differs from zero, said acceleration being directly proportional to, and in the direction of, the vector sum of the forces, and inversely proportional to the mass of that body. This condition represents a departure from a state of equilibrium. Then, please, let us not confuse the student by telling him that this vector sum of the forces is balanced by the "inertia force" or "kinetic reaction" equal to the mass times the acceleration. We teach a student to isolate a body and determine the resultant of all the forces which cause acceleration. Then let us encourage the student to relate this cause to its consequence, the acceleration of that body, and not confuse this acceleration with another force.

The great majority of physics texts until recently have been deficient in their treatment of the location and identity of the forces operating in a given dynamical situation. In this field many of the physicists have had to learn from the engineers. However, there is a growing realization among physics teachers of the desirability to emphasize the isolation of an advantageously chosen body of a system and to identify all the forces acting on that body. The physicists might advantageously cultivate the use of the terminology "free body" to accord with that of the engineers. However, the habit in some texts automatically to tack the word "diagram" onto the words "free body" whether or not the context refers to a diagram, is scarcely to be emulated.

One of the chief uses of Newton's third law is to aid in identifying and evaluating the forces acting on the free body. It is very gratifying to find that the speakers for both the engineers and the physicists stress the importance of more attention to Newton's third law, although it has been generally and probably unjustly assumed by physicists that engineers neglect the third law. Personally, your speaker would like to see stricken from all texts the jingle and opiate, "To every action there is an equal and opposite reaction." This conveys no definite information. The most helpful statement of the law I have seen is one given by Dr. Harley Howe in his book entitled "Introduction to Physics." It reads "Every force results from the interaction of two bodies. The two bodies exert equal forces in opposite directions." Pedagogically, would it not be desirable to present this law first and follow it with the second law which evaluates the consequences of the forces?

The first law is, of course, simply emphasis of the fact that the second law still applies in the limiting case where the vector sum of the forces is zero.

Returning to the second law, why not say "the vector sum of the forces"? The dynamical behavior in which we are interested can never be determined if any of the forces on the "free body" are left out of consideration. The consistent use of the term "vector sum" helps the student to avoid pitfalls.

Most dissension over units stems

from the second law. It was interesting to hear Professor Williams refer casually to "the fundamental quantities of force, length and time." Physicists are prone to speak just as casually of "the fundamental units of mass, length and time." Is it not a mistake to take any system for granted? The experience of the present speaker leads him to feel that when students are asked to face squarely the fact that a consistent and useful system of units can be set up in several different ways and that the choice of units is really a secondary matter in the solution of a problem, units then do not present any very serious hazard. Prof. Michener's exhortation that we recognize the existence of the subject of units and discuss more than one system deserves earnest consideration.

Of course, we are not urging that departments of engineering mechanics teach metric as well as English systems in this subject. In physics we are afflicted with necessity because we must lay a foundation in our mechanics for fields, such as electricity, where metric units appear exclusively. Electricity is advantageously approached from the mechanistic point of view of the mechanics of charged particles.

In the province of vector addition the speaker wishes to take issue with Professor Williams and many other teachers of mechanics and physics in making a point of "the difference in algebraic and graphic solutions for resultants." Physically, two vector quantities have only one resultant. Its magnitude and direction are obtained by adding on to the magnitude of one of the quantities in its particular direction the magnitude of the second in its particular direction. In other words, the one vector is begun where the other leaves off and the resultant goes from the beginning of the first to the end of the second. The means whereby accurate numerical data are obtained on this resultant are quite irrelevant to the mechanics of the situation. There is an idea of vector addition which should be given to the student quite apart from the mechanics of carrying it out. I will rely on the student's resourcefulness to obtain a solution to the desired accuracy if he knows what he is trying to do. It is truly a matter of taste whether he gets the job done by relying on accurate drafting or on careful evaluation of trigonometric functions picked off a crude free hand figure. The engineering student has the background to do either.

On the other hand, when the student is told to lay off the two vectors from the same origin and then build a parallelogram, and that the Almighty says that the sum of the two vectors shall be the diagonal of that parallelogram, the whole essence of the idea of the addition of the vectorial properties is lost. The student has no more basis for regarding the diagonal of a parallelogram as the true resultant than he would for regarding as the resultant the diameter of a circle determined by the three points comprising the common origin of the two vectors and their other two termini. Naturally his trigonometry used in evaluating the resultant becomes just some more hocus pocus. Consider the student's confusion when he is then told that if he has more than two vectors to add he can forget all about the parallelogram monkey business and simply add one vector onto the next. Admittedly, placing two vectors tail to tail and then completing a parallelogram and its diagonal enables one to present two individual vectors and their resultant all applied to the same point; but we have

been told this afternoon of the advantages of constructing our vector diagrams apart from the pictures of the members the forces are acting on. Your speaker can see no advantage in working a vector problem twice by constructing a parallelogram when the triangle on one side of the diagonal of the parallelogram is sufficent and avoids the confusion we have been objecting to.

The present speaker is somewhat confused by the remarks which have been made on the teaching of moments of inertia. He has always felt it his duty in presenting mechanics to carry the student to the point where if he is given an assortment of non-concurrent, nonparallel forces acting on a body he knows how to go about analyzing the motion of the body completely in terms of a translational acceleration of its center of gravity and a rotational acceleration about an axis through this center of gravity. The speaker always deplores the use of the term, moment of inertia, to describe the identical integral when it is used for purposes of analysis in the field of strength of materials where the concept of inertia plays no role.

A divergence of opinion has been expressed between the two representatives of the Division of Engineering Mechanics on the use of the calculus in sophomore physics courses. In many of the midwestern and southern schools the matter is settled by the fact that the physics departments are forced to take some students who, because of mathematical deficiencies on entrance to college, do not commence calculus until the beginning of their second semester of physics. Excluding this group, the question still arises as to whether an already overloaded course should add to its burdens by stressing mathematical methods which will, of themselves, add to its difficulty. More emphasis on mathematical methods will often necessitate less emphasis on physical concepts. Obviously, if the students have the mathematical tools readily available they may be used to advantage in clarifying concepts. In this case the students should be required to use the calculus, for instance, in the solution of problems as well as in the development of general relations.

The disposition to apply memorized formulas to the solution of problems instead of to try to recognize in the problems the operation of fundamental physical effects which, once recognized, can usually be handled by the student by his own analytical approach, probably stems from a failure to develop self reliance on his analysis in the student before coming to college. The biggest job of a physics teacher is usually the negative one of inducing students not to rely on memory but rather to rely on their ability to reason, making use of the mathematical tools which are their own. As earnestly as we put our souls into this endeavor it is disheartening to hear Dean Schubmehl report on the student who said that his "hardest task is to "unlearn" all the formulas he had learned in physics." We physics teachers are frequently told by our students that after they are through physics they are given formulas by which to work their engineering problems. They boast that they do not have to bother to go back to fundamental principles in their engineering courses.

It is to be suspected that on formulas, as on other counts, the physics and engineering mechanics teachers are in closer agreement than either group suspects. A prime difficulty seems to be in the style of the textbooks. The text-

book writer feels that his illustrative examples should be generalized algebraic ones instead of arithmetical examples. The result is that each illustration ends up in a formula. It is very difficult to persuade the student that the purpose of the illustration is to demonstrate a method of attack instead of to satisfy the writer before presenting the final formula.

Two conclusions are brought into sharp relief by this conference: first, that we could do mutually more satisfactory jobs with our students if we were allowed more course time in which to do it, and second, that more discussion between teachers of physics and teachers of engineering mechanics would lead to a better appreciation of what each is doing.

By R. J. SCHUBMEHL

University of Notre Dame

Professor Williams is to be commended for writing a very fine paper. In the main I agree fully with his ideas stated therein, and you too I believe have heard little to criticise.

There are a few points, however, concerning which some question may be entertained. With your kind indulgence I will cite these possible points very briefly and in the order that they are discussed by Professor Williams.

I am inclined to feel that Professor Williams is a bit over-optimistic. Is the average student, starting a course in mechanics, equipped in mathematics and physics to the degree of proficiency indicated? Granted, he is able to handle the techniques of algebra, trigonometry and geometry, he seems to lack completely the ability to see or appreciate that a mathematical equation is a statement of the relation between physical quantities expressed in symbols. To solve an oblique triangle, given two angles and a side, you must use the law of sines, but it rarely occurs to him that the law of sines expresses the relation of the sides of the triangle to the angles opposite the sides. And to develop such an equation or establish such physical relations is a most difficult undertaking. The basis of this trouble dates back to grade and high school days, where analytical thought seems to be frowned upon or at least not encouraged. We should use every means possible to provoke such thought.

The average student's knowledge of physical laws seems to be of similar quality. He has memorized a number of formulas which can be used for typical problems. These formulas fail to express the condition, or result of any physical phenomena, and as a result any problem which deviates from the type is beyond solution. Why then should not the fundamental laws be stressed more, and the problems limited to just the simplest necessary to drive home a point? Speaking of formulas, just recently I heard a student in mechanics say his hardest task was to "unlearn" all the formulas he had learned in physics. This condition does not seem to be peculiar to students studying physics at any school. The large number of transfer students recently sent to us from the many colleges and universities by the Navy, gave no cause for any change in opinion.

Calculus, for the average student, is quite mysterious in its applications. At the time he is taking physics he is just being introduced to the subject, and his

knowledge of it is extremely limited. I am not so sure that it is wise to encourage the use of calculus in the physics course at this time. Would it not be better to offer a graphical representation? With his background of college algebra and analytic geometry it should not be too difficult to show the meaning and the value of, say, a time-velocity diagram and show him why the slope of the tangent to the curve represents the acceleration due to the change in magnitude of the velocity. And by a careful selection of simple time-displacement or time-velocity relations it should be no great task by means of analytic geometry to find slopes, areas, etc. It should be a simple matter to show, for instance, that $\frac{V_2 - V_1}{t} = a$ is true for only a very particular type of motion. It should also explain many of the difficulties, such as a particle having acceleration with no velocity, etc.

On the other hand when the student starts mechanics, the methods of calculus should be stressed. Perhaps it would be a good philosophy, at this stage, never to use a simpler type of mathematics if calculus will do as well. In using calculus he will soon learn (if he understands the graphic representation) that he is doing the same thing by a different means. Perhaps calculus then would have some meaning for him. Differentiation and integration will take on a significance he never thought probable. Acceleration, for instance, and its components, even if expressed as tangential and radial, will take on a new importance.

Professor Williams has expressed most cleary the difficulties encountered by the mechanics student regarding the characteristics of a force, the free body diagram and mass, and he has expertly pointed out the things relative thereto that should be stressed, and has noted the pitfalls that should be avoided. Further discussion on these topics would be excessive.

An elementary course in mechanics should demand of the student two things: a thorough knowledge of fundamental principles and a proficiency in the application of these principles. The knowledge of Newton's laws of motion is imperative. But is a statement of that law imperative in the solution of a problem? If a hypothetical condition can be assumed in problems involving acceleration, as allowed by d'Alembert's principle, and if this assumption aids in the solution of the problem for the student, I am definitely in favor of its use. The advantages to the student, I think, out-weigh the disadvantages. If he understands Newton's laws, he will readily appreciate that the condition is purely hypothetical and no false impressions should result.

The definition of moment of inertia advanced by Professor Williams is excellent. There should be a law excluding all others. The only suggestion I have in this regard is that those portions of sophomore physics courses requiring the use of the moment of inertia be eliminated. The elimination may give just a little relief from the excessive amount of material that is taught in physics in the alloted time. Finally, the problems of units. This problem we shall always have with us. I would welcome any suggestion which would tend to relieve the unit trouble. So long as the answer requested is in feet per second, the student will get feet per second, regardless of the units of the factors he uses.

Perhaps if we were allowed more time to teach mechanics some of the major difficulties could be overcome. With the trend being to add more hu-

manity hours to the curricula, it looks as if we shall be allotted less time instead of more.

In discussing Professor Williams paper I mentioned several things about the teaching of physics. I am sure a more prudent person would probably refrain from saying any more.

Prof. Michener has given us much to think about. The idea of having the physics departments meet with the mechanics departments is excellent. I am wondering if it would not be possible to have the minutes of some of these meetings published in the S.P.-E.E. journal so that the others of us might benefit therefrom. Surely the problems encountered in teaching physics and mechanics are quite common to all schools.

His opinion regarding the relative importance of teaching and research is well worth pondering over. With the publicity given to atomic physics, it is only natural that the other branches of physics should be slighted. Physics today means atomic physics. This should not be, for, whether we like it or not, we are still going to have to deal with simple mechanics. This latter point should be stressed in any guidance offered a young instructor in physics.

Prof. Michener has been well informed as to the shortcomings of the instructions. But, if the recommendations he suggests are carried out I don't see how there could be many problems remaining. The two things he pointed out, that I feel are of major importance, are: d'Alembert's principle should not be introduced at the elementary physics level and, that the equation $L = I\alpha$, as well as some other equations, are definitely limited. As was suggested earlier this afternoon, perhaps it would be wise if all topics involving "I" were to be eliminated from the first course in college physics.

Prof. Michener also suggests that teachers of physics are criticised for putting too much emphasis upon the working of problems. I think the teachers of mechanics are deserving of some criticism too and the same fault. It is necessary that the mechanics student be able to work problems, but it is definitely more necessary that he understands principles. If he knows the latter he need have little worry about the former. It might be said, though, that the mechanics student is in the transition period between the study of the theory and the practical application. For that reason Coriolis' law, the parallel axis theorem, the theorem of Pappus, and Guldinus, or any other theorem, may be used if the student is completely satisfied as to its verity.

Finally, I would like to suggest that each and every teacher of physics or mechanics give Prof. Michener's suggestion some very serious thought. I don't think that any of us is in such a position that we cannot benefit by open and honest discussion.

A Report on Mathematics Preparation for Engineering Colleges

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For the past five years, we have been observing a deterioration in the mathematical preparation for admission to the freshman year of The Cooper Union School of Engineering. This observation is the result of essentially two factors: (1) We are constantly aware of the absence of certain mathematical facts and techniques in our students' preparation, and (2) it has been impossible to cover the same ground at the same rate as heretofore.

To verify these observations, the Cooper Union Department of Mathematics called together a representative group from the several engineering colleges in Metropolitan New York to discuss the problem. The consensus at this meeting was that the mathematical preparation for the profession was no longer adequate, although there was some disagreement as to the nature of the weaknesses.

This conference was followed by a round-table panel, held four months later, among the representatives of the colleges who were present at the initial meeting and those of the high schools which are the prime sources of engineering students in this area. As far as we know, this represented a first attempt to bring together in such a manner the high school and college teachers of mathematics to discuss their mutual problems. It was a provocative session wherein certain conclusions were drawn:

(*a*) A vast majority of the high school people believe that their prime function is to educate all youth and not merely to prepare a relatively small percentage, although large in numbers, for college. Therefore, in mathematics, technique is not as essential or desirable as it was, say, ten years ago.

(*b*) The range of mathematical topics taught in the high schools today attempts to encompass the field from arithmetic through topology, including calculus.

(*c*) The high school teacher says his job is to emphasize concepts rather than techniques.

We then drew up a questionnaire to test the validity of the above enumerated conclusions and circulated it among the academic high schools of the area. Fifty-seven schools were queried and twenty-eight replied. The schools which responded may be regarded as representative of the whole group because they represented not only all New York City but also part of Northern New Jersey, Westchester County, and Long Island.

The questionnaire is printed immediately below with the answers for Part

I tabulated to the right of each problem. Because there was some misunderstanding of operational and comprehension levels, we lumped together EO and EC as E, IO and IC as I, etc. The numbers under each heading represent the number of schools treating the particular topic at the given level.

Since the answers for Part II are not suitable for a statistical tabulation, we are presenting the results at the end of the summary of the results of Part I.

QUESTIONNAIRE

Part I

A number of topics, with examples of varying degrees of difficulty, are listed below. Please indicate which examples are typical of topics treated in your standard courses, using the following key for convenience:

E = Elementary Algebra. I = Intermediate Algebra.
A = Advanced Algebra. T = Trigonometry.
X = Not treated.

For each typical example treated, please indicate also the level on which it is discussed:

O = Operational level, at which the student is expected to perform and use techniques.

C = Comprehension level, at which the student is expected to follow an argument but is not expected to reproduce it or devise similar ones.

Simplification and Reduction		E	I	A	T	X
1. $2a^2-(a-3)(2a+1)$	1.	25	3	0	0	0
2. $\frac{7}{a}-\frac{2}{b}+\frac{3a}{b^2}$	2.	26	2	0	0	0
3. $\frac{5}{x-2}-\frac{5x-4}{x^2-2x}$	3.	13	15	0	0	0
4. $\frac{1}{\sqrt{xy}-y}-\frac{1}{\sqrt{xy}+y}$	4.	1	9	8	0	10
5. $\left(a-\frac{1}{a}\right)\left(1-\frac{1}{a+1}\right)$	5.	6	21	1	0	0
6. $\frac{x-\frac{1}{x}}{x-1}$	6.	6	22	0	0	0
7. $\frac{\frac{2}{x+h-1}-\frac{2}{x-1}}{h}$	7.	0	20	0	0	8
8. $\frac{\frac{x^2}{\sqrt{x^2+a^2}}-\sqrt{x^2+a^2}}{x^2+a^2}+\frac{1+\frac{x}{\sqrt{x^2+a^2}}}{x+\sqrt{x^2+a^2}}$	8.	0	1	9	0	18

Factoring						
1. $(a+b)^2-3(a+b)+2$	1.	2	10	13	0	3
2. $2x+4y+x^2+2xy$	2.	1	5	8	0	14
3. a^3+b^3	3.	1	7	13	0	7
4. x^n-y^n (n a positive integer)	4.	2	3	15	0	8
Completing the Square						
1. x^2-6x	1.	8	17	2	0	1
2. x^2-5x	2.	7	18	2	0	1
3. $2x^2+5x$	3.	4	15	3	0	6
4. rx^2+sx	4.	2	12	3	0	11
Recognition of Form						
1. $2xy+3x-5y+2$ is linear in x and in y	1.	3	10	6	0	9
2. x^6-3x^3+5 is a quadratic in x^3	2.	1	8	13	0	6
3. $3x+2\sqrt{x+1}+2$ is a quadratic in $\sqrt{x+1}$	3.	0	2	12	0	14
4. $a^{2x}+a^x+2$ is an exponential function, quadratic in a^x	4.	0	10	10	0	8
Simplification and Combination of Radicals						
1. $3\sqrt{2}-5\sqrt{8}+\sqrt{18}-4\sqrt{32}$	1.	21	7	0	0	0
2. $a\sqrt{a}-\sqrt{b}+2\sqrt{a^3}+\sqrt{25b}$	2.	13	14	1	0	0
3. $\sqrt{a^3}\cdot\sqrt[3]{a^2}$	3.	1	17	3	0	7
4. $\sqrt{(a+b^2)\sqrt{a+b^2}}$	4.	1	6	5	0	16
Solution of Systems of Linear Forms						
1. $x+2y+3z=5,\ x+3y-z=-1,\ 2x-y-2z=4$	1.	1	19	3	0	5
2. $ax+by=c,\ dx+ey=f$	2.	11	10	4	0	3
3. $2x^2+3y^2=5,\ x^2+y^2=1$	3.	1	27	0	0	0
4. $\frac{4}{x}-\frac{3}{y}=-2,\ \frac{1}{x}+\frac{3}{y}=3$	4.	3	16	5	0	4
5. $x-3y+z=0,\ 2x-z=0,\ x-y=0$	5.	1	15	5	0	7
Functional Variation						
1. If $y=\frac{3}{1-x}$, behavior of y, as $x\to\infty$, as $x\to-\infty$	1.	1	10	8	0	9
2. If $y=\frac{3}{1-x}$, behavior of y, as $x\to1$, at $x=1$	2.	1	10	9	0	8
3. If $y=\frac{3x}{1-x}$, behavior of y, as $x\to\infty$, as $x\to-\infty$	3.	1	7	7	0	13

Complex Numbers						
1. Simplification of $(2+i)(3i-4)-7i$	1.	0	10	17	0	1
2. Expression of $\sqrt{3}-i$ in polar form	2.	0	1	22	1	4
3. Determination of fourth roots of $2+i$ by De Moivre's theorem	3.	0	1	18	1	8
Solution of Rational Integral Equations						
1. By Horner's method	1.	0	0	26	0	2
2. By Newton's method	2.	0	0	7	0	21
3. By the method of successive approximations	3.	0	0	4	0	24
Inequalities						
1. Proof that $a^4+b^2>2a^2b$ (a, b real and different)	1.	0	0	6	0	22
2. Values of x for which $\frac{x^2-1}{x-2}>0$	2.	0	1	7	0	20
Trigonometry						
1. Simplification of $\frac{\sin 2\theta+2\sin\theta}{\sin 2\theta-2\sin\theta}+\cot^2\frac{\theta}{2}$	1.	0	0	0	20	8
2. Solution of $2\cos^2 2\theta-2\cos 4\theta=\sin^2 4\theta$	2.	0	0	0	18	10
3. Solution of $\sin^{-1}x+\cos^{-1}(1-x)=0$	3.	0	0	0	7	21
4. Sketch and discussion of $y=a\sin(kx+b)$ for period, amplitude, and phase angle	4.	0	0	1	13	14
5. Evaluation of $\sin\frac{13\pi}{6}$, $\cos 2$	5.	0	0	0	25	3
Exponential and Logarithmic Functions						
1. Derivation of operational laws for a^x	1.	0	15	5	3	5
2. Derivation of operational laws for $\log_a x$	2.	0	11	10	1	6
3. Graphing of $y=a^x$, $y=\log_a x$	3.	0	4	19	2	3
4. Limitations on the base a	4.	0	5	12	1	9

Part II

Please give brief statements concerning the following topics. Indicate what is treated and in which course, what you think should be omitted, and what you would like to see added.

1. Solution of linear systems. Number of equations (n), number of variables (m); systems for which $n > m$, $n < m$; homogeneous and non-homogeneous equations; use of determinants (of what order?).

2. Binomial theorem. Proof for every positive integral exponent (n); values of n for which theorem is used; determinations of kth term; discussion of binomial series when n is not a positive integer.

3. De Moivre's theorem. Proof for

positive integral powers, fractional powers.

4. Infinite geometric progression. Discussion of limit concept; derivation of formula for sum.

5. Inequalities. Absolute; conditional; where used.

6. Methods of reasoning. Deductive method of mathematics; inductive method of science; contrast, and in what context.

7. In trigonometry course, approximately what percentage of time is spent on solution of triangles, analytical trigonometry (*i.e.*, equations, reduction formulas, transformations), spherical trigonometry? What should the percentages be?

8. In advanced algebra course, approximately what percentage of time is spent on calculus: limits, differentiation, integration, applications? What should the percentages be?

Examination of Results

Let us first examine the results of the questionnaire and then comment upon them. Finally, we shall make some recommendations which seem desirable in the light of our experience and because of the responses obtained.

Simplification and Reduction

We note that 15 schools postpone the simplification of the difference of two fractions with binomial denominators, such as item 3, until intermediate algebra.

Ten schools do not discuss such simplifications as item 4 even in advanced algebra.

Eight schools do not offer simplification of a compound fraction such as item 7.

Eighteen schools of the total do not present as relatively difficult a problem as item 8.

Factoring

One-half of the schools do not expect their students to handle a problem such as item 2.

Twenty of the schools either postpone the factoring of the form $a^3 + b^3$ to advanced algebra or do not discuss it at all.

Completing the Square

All of the schools but one expect their students to be able to handle this topic with the quadratic coefficient of unity.

Nine schools do not expect their students in intermediate algebra to be able to complete the square of $2x^2 + 5x$; six of these do not treat the topic at all.

Eleven of the total do not discuss anywhere the general case of completing the square of $rx^2 + sx$.

Recognition of Form

More than half of the schools do not stress this concept by the end of the course in intermediate algebra.

Half of the schools do not expect their students to recognize a quadratic form such as item 3.

Simplification and Combination of Radicals

Seven of the replies indicate that these schools do not discuss problems of simplification of the form of item 3.

Sixteen schools do not go as far as simplifying a form such as item 4.

Solutions of Systems of Linear Forms

Five schools do not discuss, even in advanced algebra, 3 non-homogeneous equations in 3 unknowns.

Seven of the total do not discuss homogeneous equations.

Functional Variation

More than half of the replies show that a study of the variation of a function, in the neighborhood of a point or as the independent variable goes off beyond bounds, is postponed until advance algebra or is not discussed at all.

Solution of Rational Integral Equations

This topic is treated somehow in all but 2 schools with the greatest number, 26, indulging in Horner's method; 7 taking up Newton's method involving the concept of a derivative; and only 4 using that of successive approximations.

Inequalities

Six schools do discuss absolute inequalities of the form of item 1.

Eight of the total take up conditional inequalities of the type 2.

Trigonometry

Twenty of the 28 schools take up a simplification of the form of item 1.

Eighteen schools have their students solve equations such as item 2.

Twenty-one schools do not discuss inverse functions in connection with the solution of an equation such as item 3.

Half the schools do not discuss the graphing of functions of the form of item 4. Several of the 14 which do expect their students to graph such functions do not treat such a general case.

Exponential and Logarithmic Functions

Nine of the 27 schools which answered question 4 do not mention any limitations in their discussions.

Part II

1. In general, the only cases discussed are for $n = m = 3$. Determinants are not discussed.
2 and 3. The Binomial Theorem and De Moivre's Theorem are not proved but rather discussed for positive integral powers.
4. Most schools claim to discuss infinite geometric progressions.
5. Most schools do not take up inequalities. (See Part I.)
6. This question was not answered satisfactorily and therefore we shall not comment upon it.
7. Approximately 40 per cent of the trigonometry is devoted to the solutions of triangles, with up to 30 per cent spent on spherical trigonometry, and approximately 30 per cent on analytical trigonometry.
8. The consensus here is that the schools would like to take up some work in calculus but do not have sufficient time, although approximately half do use at least 15 per cent of the advanced algebra for this work.

DISCUSSION OF THE RESULTS

We concur that it is the duty of the high schools to educate youth for life and not only take care of the sizable minority who go on to college. Also, we agree that in many instances it is not practicable to separate college preparatory students from the others. But the failure to do so results in lower standards of the total course of study and the boy who intends to pursue a college career suffers thereby.

The technical proficiency of our students is appallingly lower in general today than it was 5 or more years ago. This results from the weakened course of study. Perhaps we can state to those opposing technical proficiency in favor of surface acquaintanceship with the various fields of mathematics that the two are not incompatible. However, the boy who needs manipulative skill

will suffer if he does not experience the practice of these skills on a sufficiently high level no matter how glib he is with theories of infinity, Moebius strips, non-euclidean geometries, etc.

The level of proficiency at which a boy operates in general is lower than that at which the instructor aims. This elementary fact explains why intermediate algebra includes a wholesome review of elementary algebra and why a course in advanced calculus generally begins with the limit concept and the determination thereof, etc. In other words, it is poor mathematics as well as bad pedagogy to state that a student only has need of operation A and therefore we shall teach only operation A. As some teachers would phrase it, "Teach only that which has application." Shades of Abel, Bolyai, Galois, Riemann, et al!

The high schools today are attempting to do a dual job at once; prepare those who wish to go to college and educate others through a terminal course. The students in the latter group comprise a clearcut majority today as opposed to the academy and high school populations of 50 years ago which were heavily college preparatory in scope. Consequently a dilemma arises: What mathematics is to be taught to these students to make them aware of this one unbroken link of civilization? The answer as prescribed by the schools seems to be a relatively small degree of technique throughout the high school curriculum with a multitude of topics of interest covered in advanced algebra and other special courses.

To become more specific, the responses to the technique questions are testimony to the elimination or postponement of technics in high school mathematics courses with the result that there is a heavy mortality in freshman mathematics at college. If high school teachers of mathematics were to realize that algebra is a language for which there is no substitute, then the grammar of algebra would be taught as soon as possible in order that the student achieve proficiency by the time he reaches college. Where will those students whose schools do not treat topics such as 7 and 8 on Simplification and Reduction learn how to handle such matters? The level of difficulty encountered here is many times met in calculus problems where a working knowledge of algebra is presupposed.

To continue, the process of factoring seems to be pushed into the upper courses or not discussed at all—factoring is becoming a lost art. Furthermore, we notice that completing the square on a general quadratic function is regarded either as useless or too difficult by a large group. We should like to know how the quadratic formula is derived for these students. Moreover, how are such people expected to handle analytic expressions which many times demand this knowledge?

We can perhaps account now for the paucity of knowledge of exponents and radicals when we realize that less than half of our students are required to simplify the expression (4) under Simplification and Combination of Radicals. Does not such a topic have a rightful place in the syllabus any longer?

In the solution of systems of linear equations or linear forms we note that practically none of the schools employs the method of determinants which probably accounts for the very narrow attack on the problem. Why not? Are determinants less valuable as a tool or concept than a diluted version of the differential calculus?

We note in response to the queries

on Recognition of Form that the majority of the schools postpone the introduction of this concept to advanced algebra or do not introduce the student to it at all. The concepts of function and variation of function are primary even at the elementary stages of mathematical preparation. Yet we observe that more than half of the schools do not present the behavior of a function or else postpone it to advanced algebra but somehow teach the processes of differentiation. Apparently the phrase "continuity of a function" is unheard of in this treatment of differential calculus. Does this represent the teaching of concepts instead of techniques?

The most useful method of solving equations of higher degree is the one which is taught the least. Successive approximations employs the concept of variation of function through analysis and graphing but is put aside for Horner's method which requires needless computation and theory and also has the limitation of being useful solely for algebraic polynomials.

One final remark about the teaching of concepts! The laxity with which many mathematical concepts are taught should be overcome. We notice that a number of schools do not point out limitations on the base a when discussing the logarithmic or exponential function. Pick up a high school text on trigonometry and probably staring us in the face will be a statement that $\tan 90° = \pm \infty$. (Unfortunately, too many college texts will say the same thing!)

Conclusions

The advisability of adhering to the divisions of academic and vocational schools and the separation of college preparatory students from others is indicated. In this manner the high schools can provide those who require more mathematical skills with the necessary practice and without worrying about the value of this procedure for those who have no need of detailed mathematical training. Under present conditions, a certain group of boys has come to us with a sophistication in mathematics which is easily pricked when the time comes for doing something instead of talking about it.

We firmly believe that the colleges should not dictate to the high schools what is to be taught at that level for all students but rather indicate what is desirable preparation for college work. Thus those who intend to continue with their mathematical studies will not be the victims of anemic courses in mathematics where the bromides and jargon predominate and technics are sacrificed because they are too difficult or unnecessary for a large group.

We believe that all students who pusue mathematics either as an end or a means, beyond the secondary school level, should come to the colleges skilled in manipulation with the concepts of mathematical thinking so that an undue amount of time need not be spent on "review" of the elements. The level at which most freshmen courses are conducted today is too elementary and often degenerates into one of development of the work which should have been a part of the student's mathematical equipment upon entering college.

Therefore, we make the following specific recommendations:

1. The courses in algebra should be stepped up so that a higher attainment of skills can be accomplished at the end of each. Some of the techniques in intermediate and advanced algebra should be placed in the elementary algebra course and

then reviewed and extended in later studies. One of the ways of accomplishing this goal is by a study of functional form, another is by eliminating extraneous topics.

2. We believe that the results of the questionnaire demonstrate that the schools are not teaching concepts any better than techniques and consequently the whole course suffers. In the regular courses of mathematics from elementary algebra through trigonometry and advanced algebra, the many gaps of techniques and concepts should be closed. This can be accomplished by leaving for honor classes extended discussions of theories of infinities (we have had students with all the words on this topic because they took courses in it but couldn't do simple algebra); topology (the students from certain schools receive stimulation from the enchanting wonders of analysis situs because their instructors are versed in the subject—but they don't learn the fundamentals of algebra and trigonometry); etc. The time saved by the omission of these topics can be utilized by practice in manipulation on a higher level; by more careful treatment of derivations so that the students learn the nature of a proof; by a systematic study of deductive reasoning as opposed to inductive reasoning throughout the high school curriculum not only in geometry, etc.
3. A discussion of determinants has legal status in a regular course in advanced algebra and was a part of the syllabus not too long ago. This study should include not only evaluation of second and third order determinants but some of the standard elementary properties on rows and columns, minors, application to systems of equations of linear form beyond the third order homogeneous as well as non-homogeneous. In connection with Cramer's Rule, we have a splendid opportunity to tie up concepts of geometry and algebra through the interpretation of the systems.
4. Remove the section on spherical trigonometry from the trigonometry course. Its inclusion during the war period was based on the specious argument that spherical trigonometry was useful for navigation. Perhaps the validity of such a statement would be unquestioned if the war referred to was World War I. The modern methods of navigation are based on relatively extensive tables and devices for computation. In any event, the dire need for navigators is past!
5. The value of the trigonometry course would be enhanced if there were a greater detailed analysis of transformation of functions and if more attention were paid to the graphing of trigonometric functions of the form $y = a \sin (Kx + b)$ or $y = A \sin x + B \cos x$.
6. Re-introduce inverse trigonometric functions and emphasize radian measure. Use both more frequently.
7. If additional topics in algebra are needed, we suggest work on absolute and conditional inequalities, the graphing of more difficult functions with finite and infinite discontinuities, more detailed work on exponential and logarithmic functions and equations, etc.
8. Replace the study of Horner's method with the method of successive approximations or at least teach the latter along with the

traditional. By doing so, other types of equations can be treated, *e.g.*, exponential and trigonometric.

9. Avoid loose talk on all concepts, *e.g.*, $\tan \frac{\pi}{2}$ does not exist, $\frac{a-b}{a-b}=1$ provided that $a \neq b$, $\lim_{x \to 0} \frac{a}{x}$ does not exist, etc.

10. If the schools persist in teaching the concepts of calculus, why not teach them in a separate honors course where a sufficient amount of time can be devoted to a proper development. Under the present syllabus, the optional topics of calculus crowd out many of the desired features of a good advanced algebra course. Many of the topics which we have mentioned and which are now treated superficially in the traditional courses can be developed in better fashion in this honors course.

We emphatically believe that the high schools would be doing a much better job for the college preparatory student by following the recommendations as outlined above. Further, the American student of mathematics would progress faster in his college career if he were to pass over the threshold with the background proposed.

"Preventive Medicine" in Engineering Education

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Despite the current popularity enjoyed by public health and sanitary engineering, both intra-and extra-murally, it appears to me that one important educational phase is being immeasurably neglected. This phase, and I prefer to call it "preventive medicine in engineering education," deals with the training of engineers other than those in sanitary and public health. It is roughly analogous to the comparison of preventive and curative medicine, wherein, for instance, the engineers practice the prevention of typhoid fever by the purification of water and milk. This phase of the education of the engineer should give him sufficient knowledge to recognize industrial and domestic health problems when he encounters them, to know where to go for expert advice, and lastly, to know how to apply that advice.

A program such as this should make possible effective "stop-at-the-source" as well as "early diagnosis" of health hazards. In addition to the actual financial saving to industry itself in time, insurance, and labor relations, the service of the existing sanitary engineering facilities could be greatly expanded. Carrying the analogy further, the Sanitary Engineer would cure the hazards after they cause damage while the plant engineer, by early diagnosis or preconsultation, would prevent the hazard from arising; thus, "preventive medicine."

There are now existing glaring instances in the everyday life of the practicing Sanitary Engineer, where a minimum amount of training in public health responsibilities to other engineers would greatly assist him in his work. For example, consider the multitude of cases of "man-made malaria" caused by civil engineers through inadvertently-placed culverts and barrow pits or reservoirs, so constructed as to provide prolific breeding grounds for malaria mosquitoes. Some acquaintance with the fundamental sanitary engineering considerations involved in malaria control would completely eliminate the curative engineering necessitated. The multitude of "Cross-connections" encountered should further this testimony.

Quite frequently, architects as well as civil engineers are called upon to design food processing facilities such as ice houses, kitchens, canneries, milk plants and the like. These installations are seldom adequate from a health engineering standpoint, therefore, the experience of the average public health worker is to find much of their time and energy employed in the correction of the resulting health hazards. This could be salvaged if they were called in on initial design. One of the more serious diseases confronting the nation today, particularly in the South, is typhus fever, and one of the most important preventive measures is that of

"rat-proofing" dwellings. If the architects were advised in advance of this necessity, all "rat-proofing" activities could be curtailed. Recently the American Public Health Association has made available a pamphlet entitled "Basic Principles of Healthful Housing" which is a further indication of the trend.

How many mechanical engineers who are responsible for exhaust systems in industrial plants have a working knowledge of the noxious substances which they are required to exhaust or their physiological effects on man? For example, many noxious gases from welding, contrary to common opinion, cannot be safely removed by general ventilation because of their very low toxic limits or their accumulative effects. Quite often, due to the localization of the gases at the point of generation and usually in the face of the welder, the exhaustion of enormous quantities of air develops a false sense of security. But time and time again the industrial hygiene engineer is confronted by an elaborate general exhaust system handling large quantities of air when a simple "point" exhaust system would be the satisfactory answer.

The great majority of the noxious gas exposures come under the jurisdiction of the chemical engineer. In general, he is cognizant of the acute exposures usually encountered, and perhaps a certain amount of the dermatitis, but seldom the more insidious prolonged exposures. For instance, it was the author's experience to observe a degreasing operation using trichlorethylene as a solvent in which the unprotected workers were required to work over day after day. Prolonged exposures to trichlorethylene running literally into years result in serious physical damage and possible death, and with very little hope of repair. The engineers in charge of like processes could not be expected to be specifically informed, but had they had some advanced information they could have been alert to such hazards and called in the services of the State consultant or Federal Public Health Agencies, and more important still, had they the willingness and ability to cooperate, such situations, in all probability, could be eliminated.

It is the author's belief that in most every phase of engineering there is some marginal infringement on health. (See Table.) Furthermore, it is his belief that this health infringement is the responsibility of the engineer involved, and that by giving him the

CHART INDICATING PHASES OF ENGINEERING AND INFRINGEMENT ON HEALTH

Civil Eng.	Chem. Eng.	Mech. Eng.	Arch. Eng.	Elec. Eng.
Malaria Control	Wastes Treatment	Abnormalities of Heat or Pressure	Typhus	Housing
Water Supply	Noxious Gases	Heating and Ventilation	Kitchens	Illumination
Sewage Disposal	Food Processing	Air Conditioning	Housing	Noise Control
Waste Disposal	Mining	Noise Control	Air Conditioning	
Mining	Water Treatment			
Ship Building				
Tunneling				

necessary knowledge to recognize the hazard, to know where to go for help, and to know how to receive and apply expert advice, he can shoulder this responsibility.

It is only fair to bear in mind that any work or process that can in any way affect the worker, affects also the health and welfare of the entire community. Thus the burden of cost of such training can and should logically fall on the people as a whole. Though not advisable, making this mandatory would be reasonable.

Also as previously noted, considerable saving in time and energy of the sanitary engineer can be a result of such training. First, other engineers will become receptive to services of the sanitary engineer. They will have established a common nomenclature, while now much valuable time is lost to sanitary engineers in explaining the basic problems. Second, the sanitary engineer will no longer spend his time searching out problems. Third, the burden of minor problems will be eliminated. Fourth, time required in followups will be greatly reduced. Fifth, the sanitary engineer will have plenty of time to extend his services to new and urgently needed fields of investigation and all of this will logically result in a saving to the community at large in increased production and better living.

Realizing the engineering curricula are grossly overcrowded, it is still the considered opinion of the author that every engineer should become actually acquainted with the actual problems confronted by the practicing sanitary engineer, created by other engineers like himself. All engineers should have a speaking knowledge of food and premise sanitation; water supply, sewage, and waste disposal; and industrial hygiene. It is suggested that this material might be in the form of descriptive course work in the senior year with a supplement of film strips and movies which, it is the author's understanding, will be made available shortly through the agency of the U. S. Public Health Service.

Rather than a complete course devoted to these plans, perhaps the selective insertion of pertinent material by means of a lecture or two in an established senior course would work best. Thus, the chemical engineers, for example, might get two or three lectures on health consideration applied to chemical engineering in a senior seminar. Further, it might be possible to so schedule this material that a student could follow the course and lecturer from department to department and get all the material as well as course credit. The lecture should, of course, be developed by the Sanitary Engineering Department.

Every engineer has a responsibility for the processes that he creates, the purpose of this training would be to develop this responsibility and at the same time effect considerable saving in time, energy, and lives of all concerned, engineers, workers, and management.

Qualifications for Professional Positions in Applied Mathematics and Related Scientific Fields

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I. Introduction

Industry, government, and other organizations doing pure and applied research are now making a much greater use of men and women trained in the mathematical sciences than in the years prior to the war. This trend may be expected to continue for a long time. What qualifications should these people have in order to work most effectively? What should their employers look for? What should determine the professional ratings of mathematically trained employees in an organization? This paper discusses some of the factors of importance in answering these questions which are becoming increasingly important for industrial and government employers as well as university and college administrators. Many of the factors considered in this paper apply equally well to all professions.

The recent growing trend for mathematically trained people to find employment in industry, business, and in the great research laboratories, private and governmental, should be gratifying to those who have recognized the contribution which mathematics can make to many fields of activity. This trend indicates that the practical value of the work that can be done by the mathematical profession is receiving a much wider recognition outside of academic institutions than ever before. The new opportunities thus opened for the mathematician afford wide and interesting fields for service. Some indication of these opportunities, and the advantages to industry, business, and government which would result from use of mathematically trained people, have been discussed previously.†

The potential variety of useful applications of mathematical sciences are so numerous that they can scarcely be foreseen; certainly a rapid expansion is now in progress. The demand for people trained to do such work has increased markedly. It has become increasingly important for university and college administrators and faculties to provide appropriate mathematical training which will attract and meet the needs of students who intend to pursue these applied fields as a career. A suggested training program specifically for

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**The opinions expressed in this paper are those of the authors and are not necessarily those of the Navy Department.

†"New Frontiers" by Richard S. Burington, *Science*, March 30, 1945, Vol. 101, No. 2622, pp. 313–320.

these students has been given before,† which was intended to supplement the more common type of training leading to a career in academic mathematics.

The qualifications of a good teacher in mathematical fields have been widely discussed by many people. The qualifications of an academic research worker in mathematics are matters involving unique and individual talent; these have received much attention from professional mathematicians in the universities. However, in contrast, the qualifications which individuals in the mathematical sciences should have for work in industry and research organizations, private and governmental, have not been so widely studied, principally because relatively few mathematicians have been used outside the universities and colleges prior to World War II.

Since mathematicians are being used so widely now, it seems appropriate to discuss some of the qualifications desirable in the applied fields. It is well recognized that an individual will gain an important part of his qualifications from the technical training and attitudes imparted during his college years. With increasing interest in careers in applied mathematics on the part of both students and employers, the universities and colleges have an opportunity and a responsibility to prepare men so that they will be able to render the best possible service in these fields.

The remarks in the remainder of this paper concern general qualifications, qualifications for specific ratings, and, briefly, some problems associated with estimating how an individual measures up to desired qualifications. Although the mathematical opportunities in industry, business, and government are stressed, much of the discussion also applies to other fields, just as much of it also applies to teaching positions, and other positions more of a research character, in institutions of higher learning.

II. General Qualifications

The following characteristics are believed to be among the most important ones for successful work in industry, research centers, government, or any organization using applied mathematical fields.

Character.
Technical ability, routine and creative. Aptitude for research.
Attitude toward work.
Productiveness.
Initiative, enthusiasm, interest.
Ability to take responsibility.
Cooperativeness, loyalty, willingness to support the organization.
Trustworthiness, including proper sense of security.
Administrative ability and judgment.

Character is considered in many places to be the most important qualification, and as such receives first consideration in hiring, retaining, and promoting personnel. A comprehensive definition of the term character is too involved to give here. As Dr. Albert Hull of the Research Laboratory of the General Electric Company has so ably discussed in a recent paper,* character includes many of the virtues, such as courage, self-discipline, honesty, and generosity. He states that honesty "is the basis of true friendship and team-

† "Training of Mathematicians" by Richard S. Burington, JOURNAL OF ENGINEERING EDUCATION, December 1941, Vol. XXXII, No. 4, pp. 346–352.

* "Selection and Training of Students for Industrial Research" by Dr. Albert W. Hull, *Science*, Feb. 16, 1945, Vol. 101, No. 2616, pp. 157–160.

work, and hence is an essential requirement in a cooperating group." Research workers must not only avoid deceiving others, but must be most careful not to deceive themselves. As Dr. Hull points out, it is most important that the candidate be able to distinguish between wishful interpretation of data and the true significant interpretation of that data. The scientist must be capable of facing impartially the facts presented if he is to do a good honest job.

It is generally recognized that no research organization can afford to employ a man who lacks a generous spirit of cooperation with his colleagues. He cannot expect to receive this cooperation without giving it freely and generously.

Perserverance and endurance, along with honesty and ability to work with others, may well be even more important than outstanding mathematical or scientific ability.

In addition to all of these characteristics, there should be added the importance of personal habits and appearance. These clearly play an important role in a person's ability to make significant contributions in the long run, as well as in his ability to fit into a working organization. Such characteristics as ability to meet and deal with other people, ability to keep a keen and constructive critical sense, tact, enthusiasm, drive, neatness, and a host of others are basic qualifications desirable for almost all kinds of professional work.

A broad meaning is attached to "technical ability." Expert familiarity with the methods and results of a technical field is of course a first requisite. However, a scientist can only be productive, and his results and opinions of value, if he can do more than apply his knowledge as a technical tool. He must have maturity of thinking, breadth of ideas, versatility, and an appreciation of the relation of his subject and his work to the general program for which he is employed. Such characteristics cannot be ensured merely by passing a certain number of courses, by academic degrees, by membership in scientific organizations, or by the ability to solve problems for specific tests. Likewise, mere years of experience do not indicate a man's value, certainly without some inquiry into the nature of the experience and the success achieved.

If the position is a research one, the candidate must be endowed with a large amount of imagination, curiosity, and analytical power. This imagination must be a "controlled" one; it should include the ability to visualize new situations and to anticipate various possible consequences. Without this power of imagination, the candidate will not be apt to be useful as an investigator, though he may be extremely useful in solving certain types of problems which are set up for him to work on.

Unless a candidate for a research position has a well developed ability to size up a situation or experiment, he is very apt either to draw no conclusions at all, or else to draw the wrong conclusions. He must be able to see the balance between the main issues and the details, in order that he will not become so involved in the complexities of side issues that the principal desired results will be long delayed or overlooked.

One of the very important qualities for a research position is curiosity, research "for the fun of it." Unless a worker can derive real satisfaction from his efforts at research, he cannot develop into a good research worker.

The attitude of a candidate for a position (be it research or not) toward his work, his colleagues, and his chosen field is often of greater importance than his knowledge. If he loves his work, if he is enthusiastic to know more, if he never can find time enough to get done all the work he wants to do, during a day which is habitually "too short," then he may be a most promising candidate.

These qualifications apply equally well to every type of professional worker.

The technical accomplishments of an employee also depend on such important items as scientific "common sense," decisiveness, soundness of judgment, stability, professional progressiveness, and willingness to undertake projects in all necessary details, including routine and uninteresting aspects of problems which may be required in order to obtain useful results.

All too frequently a situation arises where a problem cannot be solved quickly, yet the broader problem of which it is a part demands an early decision. In these situations a technical judgment must be advanced. Decisiveness is essential even though there is a risk that the decision may prove to be wrong. Such risks, when necessarily taken, become appreciably less if the individual making the decisions can base them on a mature realization of the degree of guesswork involved, and if he can evaluate the consequences and provide for an incorrect guess or decision. By common sense judgment is not meant "crystal ball gazing" or mere hunches; it is judgment based on a clear knowledge of the uncertainties involved, and the extent to which the decision depends on them.

The applied scientist soon finds that tests, experiments, developments and the like are frequently not carried out in the best manner from a technical point of view. This may be irritating to him, and he will be inclined to fight for his point of view. He must soon learn, however, that there are many adjustments that have to be made between purely technical considerations and matters of expediency, practical, economical, political, and otherwise, completely out of his control. He must be able to adjust himself to such situations while maintaining his technical standards, and must show strength in steering the inevitable compromises in directions which are sensible and as nearly as possible in accord with best scientific ideals.

Stability and pertinacity are important in any work, and particularly so in applied scientific fields where practical finished "results" are expected. The individual who flits from one item to another, following his interests or merely doing the more attractive part of each task, soon finds himself at odds with his employer, even if in the long run his position requires a great versatility and knowledge in many fields.

The work of a group of scientists must be timely and must take account of changing situations. In judging an employee it is important to take account of his probable progressiveness in the future, as well as his past record. A continued constructive interest in the actual work and progress of the organization is essential, with foresight and ability to anticipate needs.

A common criticism of employees who work under a "tenure of office" or "seniority" system is that they tend to "get in a rut" and cease progressing in their professional field. This is often said of government employees, but it is equally true for many other

types of workers. They can be found in colleges, universities, railroads, industries, and many other places. This failure to keep alert and maintain interest in the progress of a science, which is constantly growing, results in a seriously lower standard of accomplishment in any organization. In some fields, where the subject is new and growing and where the competition is keen, the whole purpose of mathematical analysis would be defeated if the studies were not kept strictly up to date and in keeping with the latest developments.

A mathematician should be encouraged to maintain a professional standing among others in his field, by participation in professional activities not limited to his immediate job requirements, in so far as this does not interfere with his job. In some cases it may be highly desirable to arrange working conditions in such a way that the incumbent of a scientific position can spend one quarter or more of his normal working hours in research of his own choice. Of course the authorization of this privilege should be granted with great care and such a privilege should be subject to cancellation if the employee does not prove worthy of it or if the work load in an emergency requires its abandonment. However, some amount of activity and study of this type will actually increase the effectiveness of regular work.

Likewise the young worker in the mathematical sciences who wishes to become expert at applying his subject in a wide variety of ways should make a business of meeting people in other professions, reading papers in their fields, discussing their problems with them, attending meetings of their societies, and the like, so that he can better understand their ways of thinking and doing business and their many problems. This sort of sympathetic and friendly mixing will do much to break down the barrier which frequently grows up between workers in various fields, and will aid in the training of the individual for better things in his own chosen field. This is true of the pure mathematician also, since it will give him much inspiration and source of material and ideas for his own investigations. The outlook so obtained may aid materially in preventing his pure research from becoming glorified trivialities.

Another "outside" activity of value to the younger applied scientists is teaching. The young worker in applied mathematics, as in pure mathematics, who is striving to build up his technical proficiency will find no better training than to teach elementary collegiate mathematics for a time. This can often be done, when appropriate, in neighboring night schools, colleges, junior colleges, and so on, and a modest amount of such teaching work should be encouraged by employers since it will enhance the usefulness, understanding, and technical proficiency of the young mathematician. Likewise, in many positions, unless the incumbent has the ability to explain and write things accurately, yet simply and intelligently, he cannot hope to succeed. Such ability undoubtedly would often be enhanced by teaching experience, and this is another reason why teaching experience may be very beneficial for those who would enter research, industry or other forms of non-academic endeavor.

Circumstances of work and personalities may determine just which professional activities outside of the immediate job, such as mentioned above, can actually be carried out. In all cases, however, an inherent interest in

such activities is important. The successful applied scientist certainly must have an open and curious mind, a progressive interest, and the irresistible drive to investigate and participate in scientific activities which would make him naturally become involved in worthwhile outside undertakings involving his science. His qualifications are questionable indeed if he doesn't at least want to do such things.

The scientist in industry may not always be able to devote himself to the field he prefers or thinks he prefers. It is necessary to fit into an organization, to abide by rules and priorities, to cooperate with a general program, and, in short, to "do what the boss asks." One must do this even if he does not want to or if he disagrees with the order. This is a situation which the university teacher can avoid to some extent by directing his personal research into fields of his current liking. In industry, government or other organizations where there is a limited choice, it is essential to be able to adjust to a prescribed procedure and to understand the need for it. Of course one can make suggestions and need not accept decisions blindly, but work will not be effective if the individual feels suppressed or if he is always battling against his organization and his circumstances. Fortunately, most enthusiastic people entering an applied scientific job soon learn enough about it to become thoroughly interested and anxious to do something worthwhile. Their previous interests and their personal situation in the organization then assume only their proper minor emphasis in shaping an attitude toward the work.

Applications of mathematical methods require a great amount of detailed calculation or explanation, often of a very elementary character. While some of this work may be done by junior members of a staff, it is good for everyone to do some of this work (often drudgery), for it may be only by these detailed steps that the true significance of the processes buried in the work become clear and familiar. Hence the ability to do the detail on occasion is often a real asset.

In industry or government the work of the scientist will sometimes have to remain relatively unknown. The opportunity for personal publication may be remote, and he can expect little public recognition, or special awards for his individual contributions. The impersonal attitude of his organization may prevent his standing out as an individual in his work. He may even be required to keep to himself many of his discoveries or studies, for security reasons. Thus a qualification for a worker in these organizations is the ability to derive satisfaction from the accomplishment of the group as a whole; in general he must not expect to gain an outside reputation from his daily work.

III. Qualifications for Specific Grades or Positions

In determining the appropriate professional grade for an individual and in estimating how well he meets the general qualifications which have been discussed above, it is perhaps most natural to give principal attention to personal qualifications, education, and experience. Education and experience should, however, be used only as a guide, not as absolute standards, since the employer is not so much interested in rewarding past accomplishments as in finding helpful signposts indicating what may be expected of the candidate

in the future. Rigid formal criteria are only useful if they aid in judging the future ability of a particular individual to make contributions to the work of the organization.

Likewise, technical positions, ratings, and promotions within an organization should be based on individual merit, and not any more than necessary on the number of members in a given rank. The organization diagram should be flexible, limited only as may be required by budgets and a reasonable balance between the different levels of work to be performed. Seniority should never be sufficient by itself to determine ratings.

It is difficult to lay down specific requirements in education, experience, and accomplishments for the rating of individuals in various professional grades. The following remarks are intended only to show some of the characteristics which would be generally applicable. The existence of special cases should be fully recognized.

As a minimum requirement for a mathematician of any grade, a person should generally have completed basic courses in calculus, and in addition, differential equations and several other advanced courses such as advanced calculus, mathematical statistics, probability, vector analysis, higher algebra, function theory, or courses of similar advancement. These courses should total 30 to 40 semester hours or more. In addition to these requirements, at least 20 or more semester hours in physics, chemistry, and mechanics should be required. Such courses should be of a substantial collegiate level. In this connection, the standing of the school and the teachers involved should be taken into account. Mathematical courses which are largely historical or pedagogical in content, while of value, should not be counted in these requirements. The purpose of the required courses would be to guarantee a certain degree of maturity and facility in mathematical thinking and techniques, as much as to be sure of the specific knowledge obtained from these courses. Courses representing the same order of attainment should be required for any professional grade in any of the related mathematical sciences, such as statistics, theoretical physics and the like.

The minimum mathematical training commonly obtained by students with the bachelor's degree in engineering is generally not adequate for a professional mathematical position. Of course some engineers who are especially trained in mathematics, and quite a few engineering-physics students who hold the bachelor's degree may be adequately equipped for a mathematical position.

A bachelor's degree should generally be required for the lowest professional grades, where technical manipulation is required, but where there is no significant scientific responsibility and where most of the tasks are relatively simple and laid out rather specifically. For the next higher (but still junior) grade, where the problems are more complex and where appreciable scientific initiative, imagination, and responsibility are expected, a master's degree (or the equivalent) is a reasonable requirement. For the grades which require a considerable degree of technical expertness, along with any general responsibility for setting up problems or determining what is needed, a doctor's degree (or the equivalent) is strongly urged.

It is assumed that in general the preparation for the master's degree will include at least 20 semester hours of

graduate mathematics from a school of recognized standing. At least 50 such semester hours beyond the bachelor's degree, in addition to significant research work done in connection with a thesis, should be required for the doctor's degree. The "equivalent" of a degree need not be defined carefully here, but it should insure a comparable technical accomplishment, maturity, and future promise for technical productivity.

In determining qualifications of an individual in terms of his previous professional experience, it is recognized that some men develop more rapidly than others. The number of years of experience gained is not in itself an adequate measure of ability. Nevertheless, experience is very important, and is one of the best indications of what can be expected, when the nature of the experience is carefully considered and weighed in the light of the position to be filled. For the higher grades, particularly, the ability of a man to fill a job well depends very much on the relation of his experience, past achievement, and training to the specific job.

A standard of one year of experience might be required for the grade first above that of the beginners, three years of experience might be the standard for the next grade, and so on in steps of, say two years. However, the accumulation of experience should not be sufficient grounds for progressing from grade to grade.

In determining years of experience, it might be assumed that a master's degree will count as one year of experience, and a doctor's degree as two years of experience. The regulations should not be so rigid that deviations from the standard figures cannot be made in exceptional cases at the discretion of qualified scientists and administrators.

It is emphasized that the mere possession of a certain number of years of experience should not be sufficient for obtaining a particular grade, especially for the higher grades involving expert knowledge, judgment, and responsibility. For these grades, an additional review of qualifications of a candidate is essential. In all cases the nature of experience should be examined.

Any regulations set up for evaluating experience and training should take proper account of whether the experience and training were obtained recently or not. Work in mathematics done in the past will be of much less value if the person has not applied his knowledge in the field more or less continuously.

In order further to distinguish the sort of qualifications which might differentiate between successive steps in a scale of professional ratings, without confining the discussion merely to education and experience, it is convenient to consider a sequence of hypothetical grades. For purposes of exposition, these grades may be designated by (A), (B), (C), . . ., starting with the most junior grade.

These grades (A), (B), (C), . . . are intended to correspond approximately to a scale which might be found in a large industry or research organization, or in some types of government service. They may further be thought of as roughly similar, in some of the large universities, to the ranks of Junior Instructor (Assistant), Senior Instructor, and so on up through the positions of Department Head, Dean, and Head of a Research or Experimental Division. However, these comparisons are suggested only to indicate

a general scheme for discussion; the classifications (A), (B), (C), . . . are not to be considered as those necessarily in use by any particular industrial, government, research, or university organization. Each organization should of course have a system of classification which fits its individual needs and problems.

The responsibilities and privileges suggested herein which might be connected with each grade are quite similar in many respects to the qualifications mentioned by D. T. Canfield in an excellent article about college teaching positions.*

The people in grades (A) and (B) may be considered mainly as "assistants," partly in the process of training, with little direct responsibility and requiring considerable guidance on all tasks. Grade (C) requires some scientific responsibility and initiative. Appointment to this grade may carry with it a presumption of perhaps two succeeding annual reappointments, but there should be no presumption of permanent reappointment nor any obligation for promotion after several years of service. It should be clearly understood that not all meritorious grade (C)'s can be promoted, that reappointment after the first year's service implies satisfaction with the individual's work as a (C), but gives no assurance that further promotion will follow. Promotion to the next grade should not normally take place until after two or more years of service as a (C). It is believed that people with this rating should not necessarily expect to work out a career in a single organization. They should be encouraged to broaden their experience by at least some period of connection with another group within the establishment or elsewhere in industry or a university.

The rating (D) should be recommended only for a candidate who has a record of considerable professional attainment, and who may be considered as a technical "expert" on some level. He should have a recognized record of accomplishment in research or industry, and should have demonstrated his ability to deal with others effectively. An individual should not be recommended for a promotion to grade (D) who is definitely judged unworthy of promotion beyond that rank, although there should be no presumption in appointing an individual to a (D) rating that he will in due course, and as a matter of course, receive promotion to a higher rank. After promotion or appointment to a (D) rating, there might be a presumption of reappointment for at least two years. After two or three years, an individual in this grade should be encouraged, as in the (C) grade, to gain experience in other positions in the establishment or related establishments.

The rating (E) in mathematical fields should be recommended primarily as a step in the line of promotion to those men whom the organization is willing to keep and in due time probably promote further. Although promotion to an (E) grade should not be understood to insure further promotion, it should carry with it reasonable assurance of continued employment. It should be considered as evidence of recognition by the organization that the individual concerned has demonstrated definite abilities as an investigator, research worker, or producer,

* "How to Select New Members and Promote Old Ones on Our Engineering Staffs," by D. T. Canfield, the JOURNAL OF ENGINEERING EDUCATION, September 1945, Vol. 36, No. 1, pp. 43–47.

and the capacity for continuing growth and usefulness.

The rating (F) should be recommended only after careful consideration of the individual's character, scholarship, productivity, ability to work with others, value to the organization, and reputation among his peers in his own field. It should be recommended only for men who have been so tested that there is a reasonable certainty of their continuing usefulness to the organization throughout the remainder of their working years. It should be reserved as a mark of distinction in the field of professional attainment and scholarship, and should not be granted as the reward of seniority only. It should not be granted as a recognition of usefulness in administration only.

The ratings above (F) should be given only in certain special cases. It would be assumed that such men have all the technical and personal qualifications for an (F) rating, but that in addition they are capable of handling the positions of high responsibility, technical and administrative, which would warrant these high ratings. The selection of such men cannot be made on the basis of formal qualifications, but should be made only after careful consideration by properly qualified administrative personnel. The choice between grades higher than (F) should depend in part upon the administrative level of the responsibilities, assuming the individual is otherwise qualified.

In some cases, a person in the higher grades, say from (E) on, should be able to handle administrative matters of some importance and responsibility, and should be able to direct general projects or studies by a group of professional employees. However, a man's rating should not necessarily depend only on his administrative responsibilities or the number of people under his immediate supervision. In some cases he should be eligible for a high rating solely on the basis of his personal scientific productivity and attainments.

Too much emphasis cannot be placed on the significance of the above statement. Creative ability must be recognized. As it stands now, a good scientist usually must seek administrative responsibilities if he is to receive a reasonable remuneration. This only too often results in the loss to the community of the continued productivity of the scientist. The same premium must be placed on scientific excellence, attainment, and productivity as has been placed on administrative ability and accomplishment.

If such a system of grades as sketched above is followed, an employee can know what he might well expect as his career develops. Something of the sort is generally needed in order to organize work and responsibility effectively. The existence of such an organization of grades will often go a long way to prevent misunderstanding and future embarrassment both on the part of the candidate and the employer. It should be stressed, however, that in a scientific organization, and particularly where research is involved, grades and rank should be very much in the background during the course of ordinary daily work. If the system is set up fairly, and if the employee has confidence in his relationship with the administration, then he will be not unduly concerned with matters of grade and his productiveness and morale will be high. The administrative functions for which the grades were set up will then be accomplished with a minimum of effort and personal feelings.

IV. Concerning Procedures for Determining Qualifications of an Individual

It seems clear than an individual's ability to meet the broad qualifications discussed in this paper cannot be well assessed by a simple written examination on mathematical subjects. The ability to solve set problems in, say, calculus or statistics, in a standardized test can indicate little about a man's probable value to an organization, and would be completely inappropriate for the higher grades. Such abilities can be better determined by consideration of past performance when necessary. Elaborate written tests of "personality," character, and the like have also been devised, and may serve some valuable purposes. Without discussing the ramifications of these procedures, a few remarks may be made about some other desirable aspects of the process of judging an employee, over and above the formal "application blank," qualifying examinations, and the like.

The judgment of a man's technical maturity and broad abilities can best be made by scientists who have attained some recognized standing with regard to these same qualities. Thus the principal judgment of an employee should be made, not only by an administrative personnel officer, but by scientists in the same general field as the employee. In addition, it may be desirable for related technical administrative or management officials to review the qualifications of a candidate from the overall standpoint of the general interests of the business, industry, or laboratory at hand. Such judgment would presumably require extensive interviews, possibly by several qualified scientists. It would require a review of formal qualifications in the way of schooling, experience, and past accomplishments. It would also require, and as a very important step, the obtaining of first-hand opinions concerning the prospective employee from previous employers, associates, and teachers. This last could be accomplished in part through letters of recommendation, but these should be more than perfunctory. Actual interviews are desirable with previous employers, and discussion with men who know both the past experience and the potentialities of the man.

The ratings for the high grades in particular should be determined by qualified scientists and administrators in high positions in the establishments, who are familiar with the position to be filled, in the light of its relation to other scientific positions. These men should be familiar with the status of scientific workers in institutions of higher learning, industry, and other establishments in and out of government. In making the classification, account should be taken of the current competitive market for professional and scientific personnel. It is important not to set rigid rules which will prevent necessary adjustments to allow for fluctuations in conditions from year to year.

A trial or probationary period of employment should be initiated, with a review and new evaluation at the end of a set time. Even after careful preliminary judgment, it is probably important to learn of a man's true ability to fit in a particular organization and to do worthwhile work, by actually trying him out. A generally well qualified person will not always work out successfully in a particular set of circumstances. Both the employee and employer should appreciate the value of

finding this out during a period when they will have a mutual understanding of the new relationship which is being established.

A fair system should be set up for periodically reviewing performance, or otherwise ensuring that an employee is living up to the standards of his grade. It may be that a routine formal efficiency rating system is not in itself sufficient for this purpose.

Finally, it should not be made administratively or legally impossible to reassign men in an organization if the total accomplishment would be materially advanced thereby.

What the Electrical Engineering Department Needs from the Drawing Department*

By W. A. LEWIS

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In the practice of electrical engineering many types of drawings are needed for the transmission of accurate technical information from the mind of the designer to the constructor, installer, and user of electrical equipment. The same types of construction drawings that are required for the construction of mechanical equipment are needed by the electrical engineer. These drawings include three-dimensional projection drawings of parts and assemblies, as well as outline drawings for installation purposes, and process drawings which are useful in construction operations. The latter include particularly isometric or other pictorial projections that have proved so useful in the rapid training of industrial workers in assembling war material. In addition to these drawings, however, the electrical engineer requires several kinds of electrical drawings which are peculiar to electrical work. In general the curriculum in electrical engineering in most of the professional engineering courses makes little or no attempt to provide instruction in these special classes of electrical drawing technique. It is assumed that the knowledge required can be absorbed incidentally in the electrical courses or after graduation in the first years of practical work. The purpose of this paper is to discuss these special needs of electrical engineers with relation to the drawing instruction in the electrical engineering curriculum.

The special drawings of electrical engineering fall broadly into the following three classes:

I. Wiring diagrams.
II. Elementary and schematic diagrams.
III. Lighting plans.

Wiring diagrams are intended broadly to show the actual physical connections of the conductors to the various pieces of equipment and are usually the drawings used for construction purposes. In these drawings the symbols representing the equipment are normally located in their proper relative physical locations with respect to other apparatus, but the electrical parts of the equipment are represented schematically by means of conventional symbols which indicate the function rather than the appearance of the parts. In most cases a wiring diagram could also be made in the form of a pictorial drawing such as a three-dimensional projection or an isometric or perspective drawing, but the cost would in many cases be prohibitive, and frequently the information

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would be portrayed less clearly. In contrast with wiring diagrams, elementary and schematic diagrams are usually made for the purpose of analyzing the electrical functions of the equipment, and the various pieces of apparatus are represented by functional symbols which are grouped in the most convenient manner from the standpoint of explaining their function, usually without regard to the relative physical location of the parts. The symbols representing the various functioning parts of a piece of apparatus may be widely separated on the diagram but will be related by letter or number symbols that have now been standardized for the most common applications to aid in rapid understanding. Lighting plans are another group of special drawings making use of conventional symbols and are usually superposed on architectural drawings to show the installation of the wiring in buildings for lighting or power purposes.

The conventional symbols and signs used on these drawings have been developed over the years to a high state of perfection. The electrical engineer who is not thoroughly familiar with the drawings applying to his particular type of work is seriously handicapped in the pursuit of his profession.

The programs of employers in industry for the early training of college graduates within the business differ widely, but many who employ engineers for design work feel that one of the best forms of introductory work for acquiring rapid knowledge of the equipment and processes of manufacture is a period of apprenticeship in the drafting room. Although present-day students often resent the prospects of a period in the drafting room, most of the design and construction engineers who received their practice training in this way consider it invaluable. Perhaps part of the lack of interest of present graduates in a drafting room apprenticeship is due in part to their lack of proper preparation for it, and much of this difficulty might be overcome by varying the early training in drafting to suit more nearly the later requirements.

In most engineering curricula the courses in engineering drawing have developed along traditional lines to meet the requirements laid down by mechanical and civil engineers, and it is rare to find any curriculum which recognizes the existence of special drafting needs in the field of electrical engineering. The course for the most part consists of instruction in mechanical drafting and descriptive geometry with practice in the simpler types of lettering. Drawings devoted to the representation of machine parts almost always portray purely mechanical devices without any recognition that electrical equipment exists. The reason for this state of affairs may largely be traced to the fact that most drawing courses are given in the mechanical or civil engineering departments or in a separate department of engineering drawing which is staffed almost entirely by engineers with mechanical or civil engineering training, and their examples are chosen from their own experience. Electrical curricula were developed mostly as options or variations in the mechanical engineering curriculum, with electrical courses being introduced first in the senior year, later in the junior year, and in recent years starting as early as the middle or the beginning of the sophomore year. Rarely if ever does any electrical engineering invade the freshman year, and the drawing courses have been little modified by any needs of the electrical engineering curriculum. Suggestions for modification

of the drawing courses for electrical engineering students are easily resisted on the grounds that the basic courses should be the same for all kinds of engineering students, and that overspecialization should be avoided. A study of the problem indicates, however, that this matter might well be carefully reviewed as curricula are revised in the reconversion from war training to peace-time training.

In the ideal drafting course for an electrical engineer the student would of course have to begin at the same point as at present and learn the same fundamentals. However, the work in descriptive geometry, while of definite value in training the student in physical visualization, has much less intrinsic value to an electrical engineer than perhaps to other engineers in the practice of their profession.* The substitution of electrical diagramming for some of this work may well provide equal general training with greater utility. By this and other changes throughout the courses in drawing and descriptive geometry, they could be made much more interesting to him and of greater value. One of the easiest steps to take is to give attention in mechanical drawing to the representation of electrical machines and equipment or the parts of such apparatus. Certainly the same types of problems would have to be studied but the result would be of greater interest because it would tie in with the student's major field and could be used to familiarize him with the construction of equipment which he must later study in detail. Circuit breakers and control equipment also offer interesting problems for mechanical as well as electrical engineers. As early as possible in the course some attention should be given the various types of diagrams and emphasis should be placed upon the existence and desirability of standard conventions and symbols. In the first or second year where most of the drawing courses have been given, the student does not have sufficient knowledge of electrical engineering to understand thoroughly or to make complex diagrams, but he has had enough electrical work from physics courses either in high school or college to trace elementary circuits and to make simple diagrams using the conventional symbols. If time permits, a course in the junior or senior years devoted to more advanced problems of electrical engineering drawing would always be extremely advantageous.

These changes are neither radical nor extensive but would materially improve the training of the electrical engineer for his profession.

Another factor which should not be overlooked is the matter of professional interest. The entering electrical engineering freshman frequently has little knowledge of the electrical field, but some rather vague ideas about the possibilities in radio, communication, electronics, or power have induced him to study electrical engineering. However, he seldom comes in contact with electrical engineering professors or with other than elementary apparatus until the middle of his second or perhaps the third year of his course. Any curriculum changes which bring electrical engineering subjects to even a slight degree into the freshman and early part of the sophomore years will quicken his interest and help to confirm or refute his choice of electrical engineering as a career. Even in those cases where it is felt that no specialization should be made in the first years, the introduction

* The survey of engineering graduates referred to by Professor Aakhus in his companion paper lends support to this statement.

of electrical drafting to a limited extent in a common drawing course would help to give the students of all branches of engineering the information upon which to base a choice of the course to be followed in later years.

As with all suggested changes in engineering curricula, there are difficulties in realization. The curriculum is always crowded, and the introduction of any new subject forces out some of the old. To one who has been trained in a field other than electrical engineering it is very easy to say that the present course content is much more essential than any specialized training for the electrical engineering field. There is always the clamor against overspecialization, and the fear that one branch of engineering will be unduly favored. Seldom is the drawing staff well qualified to teach electrical drafting, and if the material is not well presented, its value will be nullified. Finally, the student's knowledge of electrical engineering is not sufficiently advanced in the freshman and sophomore years to make it possible for him to profit as much as would be desired from instruction in electrical drafting.

In spite of these many difficulties it is the writer's belief that substantial improvement can be made without increasing the total burden of the course. To substantiate this belief some experiments were conducted while the writer was at Cornell. In the pre-war curriculum at Cornell the freshmen were given a one-credit-hour orientation course during the first term which consisted initially of a group of lectures given to all freshmen followed by group lectures given by members of the staff of the individual departments to the students in each branch of engineering. As a result of some changes in the shop and surveying courses, it became possible to extend this one-hour course throughout the freshman year, and advantage was taken of this opportunity to conduct some limited experiments with regard to the possibility of including exercises in electrical drafting in the freshman drawing program. This one-hour course was arranged so that either a common lecture could be given to all the electrical engineering freshmen or they could be divided into small sections for a three-hour drawing period. A lecture might be given one week to be followed in the next or some later week by a three-hour practice period in which an exercise related to the lecture could be given. In these experiments two lectures and homework reading assignments were given in studying electrical standardization and standard graphical symbols used on electrical drawings. This was followed by a drawing period in which the students were asked to make a schematic diagram of a current-limit three-step motor starter for a direct-current motor. The students were given an elementary diagram of a two-step starter, like that shown in Fig. 1, and with a moderate amount of explanation they had no difficulty in determining how to modify the diagram given so that it was applicable for a three-step starter. In another period they were given a complete elementary diagram similar to that of Fig. 1 and a partially completed wiring diagram, and they were asked to copy and complete the wiring diagram according to good practice. These exercises served not only to acquaint the students with electrical diagrams but also formed an introduction to the intriguing subject of automatic devices and control. The interest in these problems was for the most part extremely high, and results were equal to expectations. Further development of

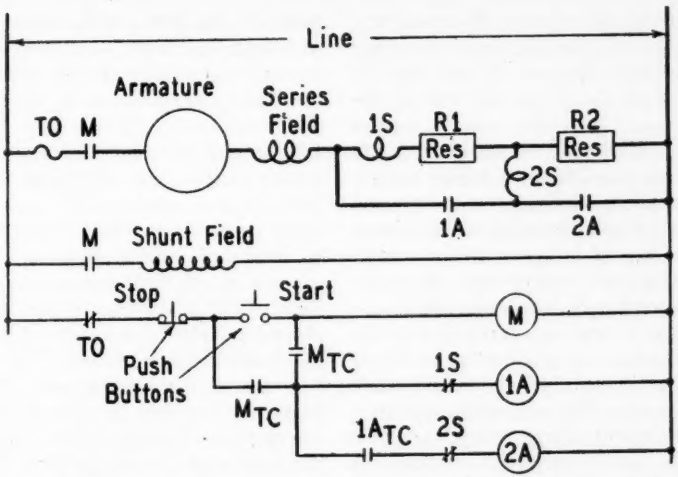

FIG. 1. Elementary diagram for a d-c motor automatic starter, using series relay acceleration. M = Main contactor; 1A, 2A = Accelerating contactors; 1S, 2S = Series relays; TO = Thermal overload relay; TC = Time delay on closing.

these ideas and any possibility of introducing similar exercises into the regular drawing courses were prevented by the establishment of the V-12 curriculum which provided no latitude for such experiments. However, with some care and attention, several varied exercises in metering, control, radio, electronics, and building wiring, having attractive features both from the standpoint of teaching drafting technique and providing an interesting insight into future electrical work, can be developed. By replacing some of the existing exercises in the conventional course a large part of the objective can be achieved without appreciably increasing the time spent, and it is believed that the advantages of these changes will well justify their introduction.

As stated above, the staffs of most drawing departments are not well equipped to develop such course changes without help. However, most engineering schools have on the electrical engineering faculty at least one member who has had sufficient experience in electrical drafting practice to provide the necessary coordination for these improvements. In some cases it would even be desirable to arrange for a member of the electrical engineering staff to conduct the class periods in which these changes were introduced.

Another innovation that should be considered in curriculum revision is a junior or senior course devoted largely to electrical drafting. By the junior or senior year the student has progressed far enough in his electrical training to be able to understand and to make more complex and complete diagrams which can tie in directly with his other courses. Such a course may be developed as part of a program in electrical design, in electrical control, or purely on its own merits. In the years just preceding the war electrical design

courses as such were in ill repute and were gradually being dropped from the curriculum. This is largely due to the fact that design of conventional apparatus such as generators or motors is an extremely difficult subject to teach in a short time, because ability to produce a rational design from the ground up requires a long period of experience and the use of judgment which comes only with that experience. As a result, too many design courses degenerated into a routine of filling out design sheets of standard form, with inadequate knowledge and with much guess work. The end result was a lot of slide rule pushing which had little interest and contributed nothing to real training. However, the attempt on the part of a student to apply his knowledge to the development of a new design has valuable educational aspects. A course in design built around the problem of developing circuits for radio, electronics, or control equipment can offer many advantages with much less of the boredom inherent in filling in the blank spaces of standard forms. The classroom periods would be devoted to a study of the particular type of apparatus and the design requirements, with emphasis on the interrelations of the circuit elements rather than on the physical proportioning of the elements themselves. The laboratory practice would then consist to a certain extent of developing the circuit diagrams to obtain the desired functions for the equipment being designed. A course built along there lines by a properly qualified instructor would do much to revive interest in a "design" course.

A similar combination may well be worked out in courses specializing on control, both electronic and electromagnetic. In this field of electrical engineering the ability to trace and understand complex diagrams is vital, and the increased emphasis on automatic control which has developed during the war will draw particular attention to this subject in meeting the post-war requirements of industry. Nothing will develop skill in reading and understanding complex diagrams like practice in trying to make diagrams of the same sort. It will thus be relatively easy to develop a course in which the classroom time is devoted to the study of circuit applications and the laboratory time to the reading and making of diagrams that will be of value and interest to the student. Particularly, in the case of the more complex types of control, it is hardly feasible for school laboratories to have such apparatus for physical experiments, but knowledge of the same or even greater value can often be gained by the proper study of diagrams after a limited amount of experience with actual control apparatus in the laboratory. Even in the present crowded four-year curriculum such courses may well deserve space, if not as required courses, as least as elective courses for those students expecting to enter manufacturing operations.

Some of the vocational schools and technical high schools have not missed the important advantages of coordinating the drafting work with the related theory and have done much to insure that their graduates have a good knowledge of electrical drafting requirements. It is true that the students of such institutions are frequently being trained directly for permanent positions as draftsmen, so that emphasis on the drafting phase is more important from its utilitarian standpoint than to the professional engineering student who does not expect to spend a large part of his professional career over a draw-

ing board. However, men trained along these lines are able, when they first enter industry, to take hold of their new work extremely well, and they will ordinarily reach industry two or perhaps three years earlier than the professionally trained engineer of the same age. With further night-school study during the first two or three years of work after graduation and with the ability to acquire knowledge rapidly because of greater familiarity with drawing technique and with actual practice in the transmission of information through the making of drawings, well trained vocational school graduates may very well give professionally trained college graduates much greater competition for design engineering positions in the future than they have in the past.

In the return to peace-time training after the strenuous activities of the war period, all engineering curricula should be carefully reviewed to make sure that the material retained is in keeping with modern needs and that it is not retained simply because it has been there for many years. The trends in available engineering positions have been away from emphasis on the design of single major pieces of equipment toward their application and the design of systems and controls which meet present-day industrial requirements. As a part of this trend, electrical diagrams will become a more important tool than in the past, and this may be profitably reflected by giving more attention to it in whatever way is possible in the development of the electrical engineering curriculum.

Some Aspects of Engineering Education in South America Especially in Uruguay*

By S. GERSZONOWICZ

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This paper will refer chiefly to education in the field of engineering in Uruguay, but references to conditions in other countries will be made on certain points to give a more complete picture of South American practices.

The University of Montevideo is not situated around a campus. Its various Schools are distributed throughout the city. The campus system in Latin American countries is found as one goes north. For instance, the University of La Habana has a campus. They are building one in Caracas, Venezuela. There is at the present moment a project to centralize the Schools of the University of Sao Paulo, Brazil, around a campus. This project, however, will not include the School of Medicine and the hospitals which are modern and too large to move.

Our University consists of nine Schools (we call them "Facultades") that are practically independent of each other. They are the Schools of Engineering, Architecture, Law, Economics, Medicine, Veterinary Medicine, Odontology, Agricultural Sciences, the Humanities and Sciences. Basic courses are taught separately in each School. For instance, each School which gives courses in mathematics has its own courses and professors. Some of our professors believe that it would be preferable to teach the basic courses of all the Schools in one place. However, those who prefer the present system claim that this is the only way to be certain that the student will receive the proper basic background which he needs in his particular school.

Each School is governed by its own Council and is presided over by a Dean. He is elected by the Councillors for a period of four years and can be reelected only once. For this position the Dean receives a remuneration of $140 per month. Besides the Dean, the Council of the School of Engineering consists at present of ten members, each of whom is elected and receives no remuneration. Only four Councillors are professors, and they are elected by their colleagues. Two are civil engineers, elected by the civil engineers; one is an industrial engineer elected by members of his profession; and two are geodesists elected by the geodesists. The tenth is an engineer who is elected by the students and who agrees to vote in accordance with the instructions he receives from the student authorities. The Council decides matters of policy and carries on other important administrative functions. On matters such as a modification of the curriculum, the

* Lecture given at Harvard University on October 30th, 1946.

Council may require the opinion of the Assembly of the School, composed of all professors and student representatives. Each School is represented on the Central Council by its Dean and one Councillor. The Central Council is presided over by the Rector of the University, elected by the Councillors of all Schools.

The University of Montevideo offers courses free of charge. A student enjoys the privilege of attending classes without paying any tuition, and he has no laboratory fees. No charge is made for the replacement of equipment that is damaged during experiments. The diploma costs $70 but a graduate who obtains an average of 12 out of 15 in his examinations receives his diploma free of charge. How then is a university system financed in Uruguay? A large part of our finances comes from the government. Each year the Central Council submits to the government and the chambers a budget, frequently including recommended raises in salaries and expenses (which are seldom approved). Private endowment is practically nonexistent in Uruguay. However, we receive regular donations from State industrial plants. The normal expenditures of the School of Engineering for the purchase of books and equipment are approximately $17,000 a year. Of this sum, $12,000 comes from the government and $5,000 from the State industrial plants. However, with the sanction of the government and chambers, special sums can be obtained. We have, for example, received about $1,000,000 for the construction of a new building for our School, which is now nearly completed, solving the problem of space which was acute in the old building.

Before the war there were a few important European industrial companies which made donations to our School or offered equipment at substantially reduced prices. Now our new laboratories will be considerably more complete than ever before, thanks to the American industrial companies that are constructing a hydroelectric power plant of 100 MVA, 150 miles from Montevideo. The energy which this plant will make available will give further impetus to our already rapidly developing industry. The need for more specialized engineers in Uruguay has become even more apparent by the construction of this plant and Mr. Giorgi, its General Manager, and former Dean of our School of Engineering, has asked the industrial companies to aid in the completion of our laboratory equipment. Through the hearty cooperation of the Westinghouse Electric International Co., the laboratories of the electrical engineering department will be the very best equipped ones for power engineering. Other companies are contributing to the development of our laboratories, which in many fields will be on an equal footing with the best equipped schools.

There are many other schools in South America which have very limited financial means, but some are quite well-off. For instance, the School of Engineering at Sao Paulo, Brazil, has rather extensive resources. Their Electrical Engineering Department spends about $40,000 a year for the purchase of laboratory instruments and apparatus. This sum is increasing every year, and, if necessary, they may have additional credits. The money comes from the province of Sao Paulo. However, the School of Engineering in Rio de Janeiro, which is a national school, spends a much smaller amount.

Our School of Engineering includes the following 9 departments: Testing

of Materials, Machinery (thermic and hydraulic), Chemistry, Electrical Engineering, Structures, Technology, Physics, Mathematics and Statistics, and Soil Mechanics. These departments give the corresponding courses in engineering and perform tests that are required by the state agencies, private individuals, and companies. They also give technical advice to state institutions and carry on research. Usually, the director of the department is the professor of all courses given in his department.

The School of Engineering has a Central Library and departmental libraries. The technical staff of the department is available to advise readers where specific information may be found. The books that are frequently consulted are generally duplicated in the central and departmental libraries. Although several copies of text-books are available, we encourage students to buy their own.

The Faculty includes full professors, associate and assistant professors, instructors, heads of departments, chiefs of laboratories and laboratory assistants. The appointments may be direct, on a standard of merit only, or on a competitive basis, requiring an examination. The Council of the School determines what procedure will be followed in each case and exercises the power of appointment. Some Universities—Sao Paulo and La Habana, for instance—make appointment only on a competitive basis including an examination. All first appointments in Uruguay are for a period of one year. After this initial appointment, all successive ones are for a period of five years. This system has not been generally adopted in other countries. In Argentina all professors, whether full professors, associates, or assistants, are appointed for life, while chiefs of laboratories and laboratory assistants are appointed for specified periods of time.

The salaries of our faculty members are very low. A full professor receives only $70 a month, an associate professor $50. The assistant professors are paid according to the number of hours they teach at the rate of $3.30 an hour. The director of a department receives about $230 a month, and assistants up to $100. Although the cost of living is much lower in Uruguay than in the United States, these salaries do not permit a man to devote his full time to teaching. Few members of the Faculty give their entire attention to the School. The majority of the Faculty come to the School only to give their classes and examinations. In Argentina the situation is no better, but it is worth mentioning because of the system of progressive salaries. The salary of a full professor in Argentina starts at about $90 a month and over a period of thirty years rises to as much as $150 a month. The members of our Faculty earn much more in their private engineering and consultation work, and frequently what they earn as professors is but a small percentage of their total income. There is, of course, a trend to modify this practice and to have full time professors in basic courses and full time and regular part time professors in application courses. Our Dean, Ing. Maggi, has presented a program of reorganization along this line with increased salaries for faculty members which, if approved, will give a new impetus to teaching as a profession, especially in the research field. It must not be misunderstood that professors are this poorly paid in all Latin American countries. In Sao Paulo, for example, full professors have in some cases received about $500 a month and this figure will be increased to $750. Unfortunately, as-

sistant professors at this same university receive only $120 a month.

Professors often "accumulate" courses. This means that they give several courses and receive a remuneration for each course. In Argentina a man has to be a full time professor when he gives three or more courses in the School of Engineering. In Uruguay a professor's income from "accumulated" courses is graduated downwards above $130 a month; for example, all earnings from the State over $130 a month are reduced 25 per cent, and over $230 a month are reduced 50%. In Cuba the first chair a professor holds pays relatively well—$300 a month—but the second chair gives him only an additional $60, and the third, $30. He also receives an increase of $5 for every additional five year period he teaches.

As can be surmised such low salaries have created a serious lack of an academic profession in South America. Since industry and some public services offer better salaries than our Schools of Engineering, it is impossible to expect young outstanding graduates to take up the teaching profession. The selection of faculty members is sometimes a real problem, especially in smaller universities. This problem is even more acute in the appointment of auxiliary, that is associate or assistant, professors than of full professors. Auxiliary professors have to substitute in case of absence of the professors. In normal times, they may have to give very few classes, about 10 per cent in Uruguay, even less in Argentina. Under such conditions, they cannot be expected to be very much interested in their work nor do they receive a stimulus to gain wider knowledge. In Uruguay there are exceptions such as when the number of students enrolled in a course is so great that it becomes necessary to divide the class into sections, and when the number of class hours exceeds three a week, which is the minimum required of a full professor. In some cases, we have full professors acting as auxiliary professors in other courses.

South American schools of engineering offer only one degree in each field. The duration of engineering studies is 5 or 6 years, depending on each particular school. In Uruguay, primary and secondary education must be completed before college studies can be begun. There are six grades in our primary schools, and four grades in our high schools. After a student completes high school, he goes to preparatory school, which is divided into sections, one for each school of the University, except the Humanities and Sciences. The duration of the preparatory studies of engineering is 2 years, and the student must pass the examinations in all courses to be admitted for advanced studies. The duration of engineering studies is 3 years for geodesists and 6 years for engineers, civil or industrial. Young men who followed vocational schooling after primary education are not admitted to a Uruguayan university. In Argentina the situation is quite different however, and young men from vocational schools can pursue advanced studies, more or less easily, depending on the particular university. Rosario accepts them directly as well as the high school graduates; La Plata requires a short examination—the same that is given to applicants from high school. The examinations for Buenos Aires, however, are more severe for both high school and vocational school graduates, with an additional examination on cultural studies for the latter; only graduates of the National High School are exempt

from examination. These differences in admission requirements have meant that as many as 1,500 students—graduates of vocational schools—commute daily from Buenos Aires to the neighboring city of La Plata.

As I said before, in theory the duration of engineering studies in Montevideo is 6 years. Actually, the duration is much longer. I shall illustrate this by the following table:

Year	Number of graduates in a given time									
	Civ.	Ind.	Civ.	Ind.	Civ.	Ind.	Civ.	Ind.	Civ.	Ind.
	6 years		7 years		8 years		9 years		more than 9 yrs.	
1942	—	—	—	4	4	—	2	—	2	1
1943	—	1	1	—	—	12	4	—	11	—

The reasons for this longer study are: *First,* the students are working. Practically every student in his 4th year or later is working—many even in their first three years. Many work for their living; some for experience if they find a job related or useful to their future professional activities. *Secondly,* the courses are rather heavy and, to give their graduates a wide preparation for their various possible employments, the School teaches quite unrelated subjects, some of which are difficult for students with ability in some other direction. *Thirdly,* too little attendance in classes, due chiefly to too many examination periods. *Lastly* many students are interested in scientific rather than technical education, but unfortunately, our School of Engineering, as I said before, only gives the degrees of engineer or geodesist, so they are obliged to follow engineering. In Argentina some Schools of Engineering not only prepare engineers but doctors in chemistry, natural sciences, mathematics and physics. Perhaps in time, our very recently created School of Humanities and Sciences will be able to offer to those interested in pure sciences the kind of education which they desire.

At this moment we are introducing a new curriculum, which this year has been applied only in the first year studies. The former curriculum, which was still offered in the 2nd to 6th years of studies contains the following courses:

Courses common to both Civil and Industrial Engineers:

I. Mathematical analysis, 1
Descriptive geometry
Analytical and projective geometry
Physics, 1
Technical chemistry

II. General mechanics, 1
Mathematical analysis, 2
Infinitesimal geometry
Physics, 2

III. Physics, 3
Analytical chemistry
General mechanics, 2
Strength of materials, 1
Physical chemistry
Technical geology
Materials of construction

Civil Engineering:

IV. Methods of construction
Strength of materials, 2

Topography and geodesy
Machinery
Electrical engineering
Hydraulics

V. Strength of materials, 3
Tests of materials
Fluvial works
Maritime works
Architecture of engineering works, 1
Sanitary engineering
Political economics and administration

VI. Structures
Terrestrial ways of communication
Architecture of engineering works, 2
Legislation
Municipal engineering

Industrial Engineering:

IV. Elements of construction
Hydraulics
Strength of materials, 2
Mineral and organic chemistry
Technical physics (air conditioning, etc.)
Electrical engineering, 1
(electric and magnetic circuits, electrical measurements, basic electronics)

V. Testing of materials
Machinery, 1
Electrical engineering, 2
(electrical machinery, electrical welding, etc.)
Industrial technology, 1
(mining, etc.)
Industrial analysis
Industrial chemistry
Political economics and administration

VI. Industrial hygiene
Electrical engineering, 3
(transmission and distribution of electricity, radio engineering, illuminating engineering)
Machinery, 2
Industrial technology, 2
(steel, textiles, paper, etc.)
Industrial installations (layouts)
Thesis

The curriculum is rigid. The number of hours of classes per week, including theory, problems, laboratories, etc., theoretically does not exceed 30–35. Since the students, however, shorten their attendance at classes to about 18 weeks a year, instead of the full 27 (the same situation exists in Argentina), some professors—if authorized by the Dean—give supplementary hours to develop their courses completely, with the result that the number of hours a week for the student in the School frequently exceeds 40. Many professors cannot finish their courses in this shorter period so that students must prepare personally the parts which are not covered by the lectures. Of course under such conditions a detailed description of each course must be available, and that explains why our catalogs contain a much more complete description than the American catalogs. Attendance in classes on theory is not obligatory; neither is attendance at classes on problems required in certain courses. The students, however, are required to attend laboratory classes for at least 80 per cent of the experiments given.

As I already stated, one of the most important reasons why students shorten their attendance to about 18 weeks a year is the large number of examination periods which at present is 5: November–December (practically two months), February (15 days), May (theoretically 3 days, actually 7), July (15 days), and September (3 to 7 days as in May). Students taking their last examination may request to take it at any time. Of course, students who prepare for one or more examinations desert the classes several days, if not weeks, before the day of the examination.

Enrollment is not by years, but by courses. In the first year students gen-

erally enroll in all courses and follow them, but as early as the beginning of the second year many fail to take all of their examinations, and are not even able to follow all their new courses. This situation becomes worse as students advance in their studies. It is not necessary to take all the courses offered one year to follow those of the next year, but to take the examination for some specific courses, it is necessary to have passed the examinations in certain prerequisite courses.

Students study assigned books and class notes of the courses, preferring the latter. The number of courses where class notes are available is not high, much fewer than in Argentina where students publish class notes for almost every course, with or without the consent of the professors. In Argentina sometimes they also publish text books if prepared by professors, which is much better of course, since unrevised class notes frequently contain quite a number of serious errors. Many of our students have some reading knowledge of English which is taught in the preparatory schools for two years, but if possible, they prefer to read books in Romance languages. I believe that great progress could be achieved by offering an optional course in technical English in our scientific schools. Many of the present books we recommend are in English, for instance, Courant's books on calculus are our texts in mathematical analysis, Guillemin's and other books on electric circuits are used to supplement our class notes, etc.

Almost all our courses are of two terms duration. After the whole course has been given, a final examination is taken.

In our last education program we did not have partial examinations and the marks given during the year for problems, laboratory experiments, etc., did not count directly in the computation of the mark given for the final examination. In our new program which we introduced this year, partial examinations exist and have a direct bearing on the final mark. Examinations may be written or oral, covering laboratory work, discussion of projects, etc.; they are more comprehensive than in Argentina where very frequently they are only oral. For example, in electrical engineering for industrial engineers, our students first have an eliminatory written examination consisting of several problems. The length of this examination is usually 3 to 5 hours and students may consult books, class notes, etc. This is followed by an eliminatory examination of 4 or 5 hours on the laboratory experiments. Finally, a student has an oral examination of from 15 to 40 minutes. Projects in electrical engineering are not obligatory.

The students who fail their examinations may retake them in the following examination period. There is no limitation on the number of times they may retake it. The highest mark is 15 points; the passing mark is 6. The jury of examiners consists of at least three members of the Faculty.

Theoretical classes are generally lecture classes. Questions from students are encouraged. In some courses we attempted to adopt the system of indicating in advance what should be read by students in preparation for the next class where we would require them to ask and answer questions, and solve problems. This did not work successfully because the majority of the students did not have the time to do this reading. We are, therefore, trying to introduce an intermediate system whereby we shall still indicate reading

but will rapidly cover the same subject in lectures and request that students interrupt and ask for explanations on points which they did not understand in their reading. In this way, those who did not cover the reading get some profit from the lecture, and in some cases, when the questions are few, time is spared for solving problems.

In addition to classes on theory, we have separate classes on problems. These classes come generally once a week and last from between 2 to 4 hours. Usually the solution of typical problems is first illustrated by the professor. Then similar problems are given to the students to solve in class with the assistance of the professor when difficulties arise. We believe this aids the students more than only giving them problems to solve by themselves at home. Laboratory experiments lasting 2 to 4 hours are given once a week. Students receive prepared sheets with a description of the experiment and discussion of the results and are responsible for learning this material. In electrical engineering for example students must select the instruments, perform the entire experiment themselves, and discuss thoroughly the accuracy of the results obtained. Student must also present several projects of industrial layouts or civil engineering works, as well as perform some obligatory field work.

The number of students who fail to finish their studies is important and the reasons are the same as those that determine the difference between the theoretical and the actual length of pursuing advanced studies; namely, students are working as well as studying; insufficient attendance; and the courses are heavy and varied. The following statistics will give a better idea of the situation:

Year	Entered in the School		Graduated		
	Engineering	Geodesy	Engineering		Geodesy
			Civ.	Ind.	
1941	24	13	10	4	10
1942	29	22	9	4	12
1943	47	12	24	5	15
1944	37	16	17	1	16
1945	47	19	9	8	4
1946	55	13	—	—	—

The total number of students at present enrolled in our School of Engineering is about 460; 355 come from Montevideo, 40 from the inner parts of Uruguay, and 65 from foreign countries. Our Faculty has about 25 full professors and about 40 auxiliary professors.

Since there is a general shortage of engineers in South America, our young graduates enjoy very good positions which offer, as a starting salary, between $200 to $350 a month. This is very good remembering that the cost of living in Uruguay is much lower than in the United States.

University graduates, and engineers in particular, enjoy a highly esteemed position in our social life. A professional man from a foreign country who received his degree at a foreign university is subject to an examination as a general proof of his diploma before he has the right to exercise his profession or use his degree. However, without this recognition of his status as an engineer, a foreign trained engineer can be employed by a private enterprise or contracted for a government project. As a matter of fact, until recently the social position of professionals was so high that in many fields the additional fact of being a University professor did not increase it. Now, however, the professorship is highly esteemed.

The exceedingly long time involved

in pursuing advanced studies now constitutes one of the major problems for which we seek a solution. One solution which we are testing is to reform the curricula. At present we offer too wide a preparation. We shall perhaps divide the present industrial engineer's career in two, electromechanical and technological engineering; anyway, in the last year or in the last two years of study we shall introduce subdivisions, with groups of elective courses. We shall also try to shorten the length of some courses without sacrificing their present fairly high level. And lastly, we have just introduced a category of "regular" students. Regular students must attend all classes as much as 26–28 weeks a year, accept partial examinations, and only two final examination periods (November–December, and February). A great majority of the students who have entered the School this year have chosen to be "regular" students. Of course, many students who work shall have to remain "free," unless we introduce night courses. However, through these changes we hope to be able to obtain a larger and more regular number of graduates.

New Members

BATES, MAURICE E., Assistant Professor of Engineering, Massachusetts State College, Amherst, Mass. A. E. Sorenson, L. F. Rahm.

BOND, FRED C., Technical Director, Basic Industries Research, Allis-Chalmers Mfg. Co., Milwaukee, Wis. E. C. Koerper, F. T. Agthe.

BRUNO, EDWIN C., Lecturer in Engineering Drawing, Northwestern University, Evanston, Ill. R. M. Cook, S. S. Hartenberg.

CORNELL, RUSSEL M., Assistant Professor of Civil Engineering, University of Minnesota, Minneapolis, Minn. G. J. Schroepfer, L. F. Boon.

COVINGTON, WAYNE R., Instructor in Engineering, Kilgore Junior College, Kilgore, Texas. S. L. Canterbury, F. L. Bishop.

COX, JAMES E., Instructor in Mechanical Engineering, Pennsylvania State College, State College, Pa. M. S. Gjesdahl, J. S. Doolittle.

CRONK, ALFRED E., Assistant Professor of Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. N. F. Ruszaj, H. C. T. Eggers.

DANA, HOMER J., Director, Engineering Experiment Station, Washington State College, Pullman, Wash. H. F. Lickey, R. D. Sloan.

DENNISON, HUBERT E., Professor and Head, Dept. Ec. ss. and I. M., Georgia School of Technology, Atlanta, Ga. R. L. Sweigert, R. L. Allen.

DINKER, JOHN D., Instructor in Civil Engineering, University of Pittsburgh, Pittsburgh, Pa. W. Irwin Short, R. F. Edgar.

DRINKWATER, WILLIAM D., Instructor in Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. N. F. Ruszaj, H. C. T. Eggers.

FAX, DAVID H., Assistant Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. J. T. Thompson, Paul Hessemer.

FEAR, ARTHUR J., Instructor in English, General Motors Institute, Flint, Mich. C. A. Brown, G. R. Cowing.

FIXEN, VICTOR L., Lecturer, University of Minnesota, Minneapolis, Minn. A. S. Cutler, Paul Andersen.

GULDEMANN, EUGENE G., Head, Engineering Dept., Vanport Extension Center, Portland, Ore. G. M. Holcomb, F. A. Wanless.

HARRIS, WILLIAM W., Assistant Professor of Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. B. J. Robertson, H. C. T. Eggers.

HENNING, KNUTE A., Professor of Architecture, North Dakota Agricultural College, Fargo, N. D. H. S. Dixon, R. M. Dolve.

HOSTED, ED G., Associate Professor of Mechanical Engineering, North Dakota Agricultural College, Fargo, N. D. H. S. Dixon, R. M. Dolve.

HUTCHINSON, ROBERT C., Assistant Professor of Mechanical Engineering, Colorado A. & M. College, Fort Collins, Colo. J. T. Strate, J. H. Scofield.

JERABEK, HENRY S., Assistant Professor of Metallography, University of Minnesota, Minneapolis, Minn. F. L. Joseph, W. H. Parker.

KERSTEN, MILES S., Assistant Professor of Civil Engineering, University of Minnesota, Minneapolis, Minn. L. F. Boon, R. C. Brinker.

LANGFORD, THOMAS R., Teacher of Engineering, Kilgore Junior College, Kilgore, Texas. S. L. Canterbury, F. L. Bishop.

LARSEN, THORSTEIN, Assistant Professor of Electrical Engineer, Johns Hopkins University, Baltimore, Md. J. T. Thompson, Paul Hessemer.

LAWS, LEONARD S., Assistant Professor of Mathematics and Mechanics, Univ. of Minnesota, Minneapolis, Minn. W. R. McEwen, H. C. T. Eggers.

LOVE, EDWARD S., Assistant Professor of Mathematics and Mechanics, Univ. of Minnesota, Minneapolis, Minn. W. R. McEwen, H. C. T. Eggers.

MCMATH, HUGH L., Professor of Architecture, University of Texas, Austin, Texas. W. R. Woolrich, Banks McLaurin.

MEHL, ROBERT F., Professor and Head, Dept. Metallurgical Engineering, Carnegie Institute Tech., Pittsburgh, Pa. F. T. Mavis, B. R. Teare.

MOORE, NORMAN H., Instructor in Civil Engineering, Johns Hopkins University, Bal-

timore, Md. J. T. Thompson, Paul Hessemer.

MUCKENHIRN, OSCAR W., Assistant Professor of Electrical Engineering, Univ. of Minn., Minneapolis, Minn. P. A. Cartwright, L. C. Caverley.

PAUL, ARTHUR N., Instructor in General Engineering, Purdue University, Lafayette, Ind. H. C. Thompson, Justus Rising.

PIRET, EDGAR L., Professor of Chemical Engineering, University of Minnesota, Minneapolis, Minn. B. J. Robertson, H. C. T. Eggers.

POLLICK, HUBERT J., Instructor in Engineering, Kilgore Junior College, Kilgore, Texas. S. L. Canterbury, F. L. Bishop.

STAYNES, SIGWARD A., Instructor in Mathematics and Mechanics, Univ. of Minnesota, Minneapolis, Minn. W. R. McEwen, H. C. T. Eggers.

STEPHENSON, RICHARD, Assistant Professor of Chemical Engineering, Univ. of Minnesota, Minneapolis, Minn. N. H. Ceaglske, C. A. Mann.

STOPPEL, ARTHUR E., Associate Professor o Chemical Engineering, Univ. of Minnesot Minneapolis, Minn. C. A. Mann, H. C T. Eggers.

VAN WYE, RALPH A., Associate Profes sor of Coordination, University of Cincin nati, Cincinnati, Ohio. H. A. Dangel, H C. Messinger.

VEY, EBEN, Instructor in Civil Engineering Johns Hopkins University, Baltimore Md. J. T. Thompson, Paul Hessemer.

WARREN, BUELL B., Personnel Director American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 2, Ala. C. J. Freund J. J. Uicker.

WILLIAMS, ROBERT A., Instructor in Chemical Engineering, University of Louisville Louisville, Ky. G. C. Williams, W. R Barnes.

YU, YAO P., Associate Professor of Electrical Engineering, North Dakota Agri. College Fargo, N. D. H. S. Dixon, R. M. Dolve

638 new members this year

Sections and Branches

Allegheny Section. The annual meeting of this Section was held at Carnegie Institute of Technology, March 20–22, 1947, with the Chairman, D. F. Miner, presiding. The following program was presented: Philosophy, Facilities and Staff for Graduate Study in Engineering, J. C. Warner; Opportunities and Rewards for Graduate Study in Engineering, J. A. Sauer; Cooperative Industrial Programs for Graduate Study, A. J. Allen. Post-War Engineering Education—From the Industrial Viewpoint, H. N. Muller, From the Educator's Viewpoint, E. M. Williams; After Veteran Programs, What Next? H. L. Spencer; Veterans Problems—From the VA Viewpoint, E. E. Brown, Veterans Administration; From the University Viewpoint, R. P. Davis; From the Liberal Arts College Viewpoint, M. D. Brewer.

Friday noon the members and friends were guests of the Westinghouse Electric Corporation at lunch at its East Pittsburgh Works. A visit of the plant was made after the lunch. The annual dinner was held Friday evening in Thistle Hall, D. F. Miner, Toastmaster. Huber O. Croft, President of the Society, spoke on Scientists, Engineers and National Policy. Saturday morning was given over to committees and visits.

The following officers were elected:

Chairman: C. E. Bullinger, Pennsylvania State College.

Vice Chairman: W. A. Koehler, West Virginia University.

Secretary: J. W. Breneman, Pennsylvania State College.

Representative on Council for two years: D. F. Miner, Carnegie Institute of Technology.

College Notes

State University of Iowa. The ninth annual Management Course will b held in Iowa City June 9 to 17, inclusive. In order to accomplish as much a possible during this period, we plan to meet from 8:30 a.m. to 5:00 p.m., in cluding luncheon meetings, meet all day on Saturday and hold some evenin sessions. A printed bulletin describing the course more fully will be availabl later in the spring.

The course will be held under the direction of Ralph M. Barnes, Professo of Industrial Engineering at the University of Iowa, and it will be conducted i much the same way as in past years.

EXPENSES

Tuition $150.0
This includes textbooks, reference books, printed forms, and reprints of articles and papers.

Living Expenses (room only)
University dormitory facilities will be available for those wanting such accommodations. Rates are as follows:

Eastlawn Dormitory or Hillcrest Dormitory (for men only)
Single room for 9 days ..... $ 11.5
Double room for 9 days (per person) 7.7
One person in double room 15.4
Due to the shortage of living accommodations, most men will be assigned two to a double room. All double rooms have twin beds.

Noon meals June 9, 10, 11, 12, 13, 14, 16, 17 and
Evening meals June 9, 10, 11, 12, 13 and 16 ..... $ 20.0
Inasmuch as the weekday luncheon meetings are a part of the course and since we will have some evening meetings scheduled, the University Dining Service will serve these meals. Each person enrolled in the course will be charged $20.00 for these meals.

REGISTRATION

Advance registration for the course is required, enrollment will be *limited* and applications will be accepted in the *order of their receipt.* Registration and communications concerning the course should be sent to Ralph M. Barnes, 111 Engineering Building, University of Iowa, Iowa City, Iowa.

It is expected that those attending will be college or university graduates, or their equivalent, since persons of this general level will benefit most from the course. No certificates or records of previous training will be required of applicants.

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